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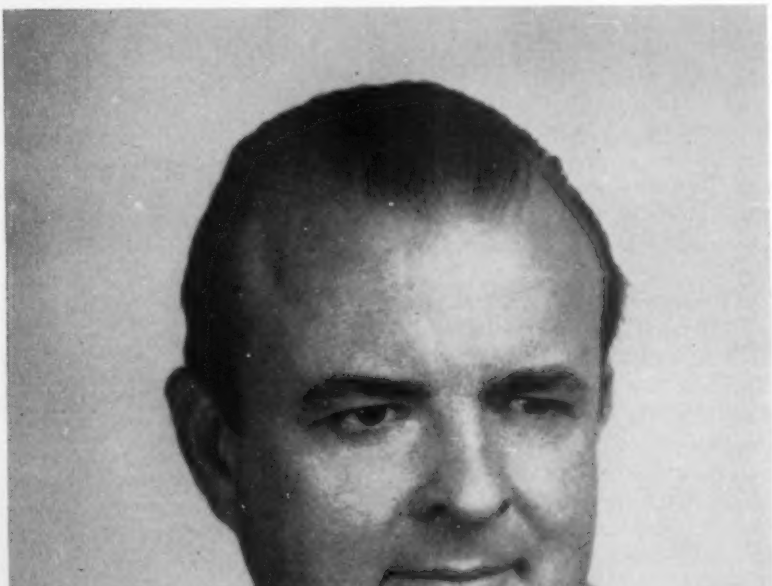

WILLIAM C. VAN DEVENTER

WILLIAM CARL VAN DEVENTER

Dr. William Carl Van Deventer was elected twenty-third president of the National Association for Research in Science Teaching at the twenty-eighth annual meeting held at Teachers College, Columbia University, April 20, 1955. He will preside at the Chicago meeting on April 21–23, 1956. He succeeds Dean Kenneth E. Anderson of the University of Kansas, Lawrence, Kansas, as president.

Dr. Van Deventer was born in Salisbury, Missouri, October 22, 1908. He married Irene Gibson in 1934. They have one son named Frank.

Dr. Van Deventer received an A.B. degree from Central College of Missouri in 1930 and M.A. (1932) and Ph.D. (1935) degrees from the University of Illinois. His master's and doctoral studies were in zoology. The title of his master's thesis was *Lecithodendrium lampei, A New Species of Trematode, Parasitic in Bats.* His doctoral thesis was entitled *Studies on the Biology of the Crayfish Cambarus propinquus* Girard.

Teaching experience includes assistant in biology at Central College 1928–30 and at the University of Illinois, 1930–34; Biologist, Monroe County Parks, New York, 1934–35; professor of biology, St. Viator College, Bourbonnais, Illinois, 1935–38; Stephens College, Columbia, Missouri, 1938–53; summer sessions at the University of Missouri 1939, 1940, 1941 and summer science education workshop, Teachers College, Columbia University, 1945. Since 1953 he has been professor of biology and Head of Department at Western Michigan College, Kalamazoo, Michigan.

Memberships in organizations include the National Association for Research in Science Teaching, Ecological Society of America, American Association for the Advancement of Science, National Association of Biology Teachers, National Science Teachers Association, and Sigma Xi. He served as Chairman of the Rural Section, Midwest International Seminar, Haslev, Denmark, in the Summer of 1949. He was Chairman of the Science Committee for Cooperative Study of Evaluation of General Education of ACE, Summer Workshop, 1950. For many years he served as member and Chairman of the College Committee of the National Association for Research in Science Teaching. Previous to this year, he served on the Executive Committee and as Vice-President of the National Association for Research in Science Teaching.

Dr. Van Deventer is the author of some thirty publications distributed among scientific and educational publications. These publications include *Ecology, Proceedings of Illinois State Academy of Science, Illinois Biological Monographs, Stephens College Publications, The Science Teacher, School Science and Mathematics, Science Education, Western Michigan College Publications,* and the *Danforth Foundation.* He contributed a chapter on *The General Biology Course at Stephens College* in *Science in General Education* (E. J. McGrath, Editor), published by Wm. C. Brown and Company, Dubuque, Iowa.

Dr. Van Deventer continues the notable list of science educators who have served with distinction as President of the National Association for Research in Science Teaching. His research studies and activities in promoting science education research have placed him high among the leaders in this area. He has a number of studies in progress and papers in process of publication. "Van" as he is popularly known among his many friends is also appreciated as a raconteur of many delightful stories.

CRITICAL THINKING AND RESEARCH *

GORDON M. DUNNING

Atomic Energy Commission, Washington, D. C.

I AM honored to be present with you today and to discuss the subject of critical thinking and research. Since you are not unfamiliar with our topic today, we will not take the time to discuss the more philosophical aspects of what constitutes critical thinking but rather devote most of our attention to concrete examples. Since many of these deal in a general way with research, broadly defined, I have taken the liberty of giving this paper its title.

In attempting to use fresh material here, most of the illustrations are drawn from the field of atomic energy. The majority of these are from the point of view that critical thinking was not well applied. I hasten to add that this approach does not mean that all we do is make mistakes in the Atomic Energy Commission, but rather it does afford a sharper, and perhaps more interesting, method of clarifying the points. Since our time is limited, I have selected only a few examples that do not require too lengthy or too technical descriptions.

INSTRUMENTATION

The advancement of research is necessarily based on a sound foundation of good instrumentation, both in terms of instrument design and use. One limitation in their use, that has become almost an axiom, is to the effect that the introduction of an instrument into an area of interest will in itself alter the original conditions.

Sometime ago, experiments were being conducted in new designs for fuel elements to be used in a reactor. One problem involved in such a design was that of safety—to fabricate the elements and define their positioning within the reactor such that the production of an excess number of neutrons would be limited to a certain value. A preliminary report on the experiments was encouraging—the number of excess neutrons present was less than calculated. However, upon further analysis it was realized that the instrument that had been placed in the neutron flux to measure this quantity was itself absorbing neutrons and thus giving an underestimate of the excess number present.

BIAS OF EXPERIMENTS

It is not the intent here to attempt any discussion on deliberate and malicious distortion of data, but rather to direct attention to the possible unwitting biasing of experiments or to the lack of recognition of this biasing when dealing with the conclusions.

It is a well known "fact" that most radiation-induced mutations have been shown to be deleterious. This has been stated in one form or another in many places, and I hasten to say that when considerably more data are accumulated, this conclusion undoubtedly will stand. But here is the point—to date, the majority of experiments by far have been *designed* to demonstrate the deleterious effects of radiation-induced mutations. Little wonder then that "most radiation-induced mutations have been shown to be deleterious." I am not qualified to attempt an explanation of why the experiments have in this sense been biased, except to point out that deleterious effects are possibly more readily and positively identifiable than are beneficial ones, or than are a third type consisting of changes that may not be necessarily in either category. For example, an experiment with Drosophilia, involving sex-linked lethal characteristics may be conducive to relatively quick accumulation of statistically manipulatable data and therefore selected in preference to one less promising in terms of conclusive results.

* Paper presented at the Twenty-Eighth Annual Meeting of the National Association for Research in Science Teaching, Teachers College, Columbia University, April 20, 1955.

USE OF CONTROLS

One of the essential features of the use of control in experimentation is to subject both the control and experimental groups to identical conditions, leaving a minimum number of variables—preferably one—to be evaluated. This is rather nicely illustrated by some bio-medical tests conducted at the Commission's Pacific Proving Ground.

In addition to the experimental group, a control group of mice was shipped from the United States to the Pacific Proving Ground. They were at the same location aboard the same ship, bounced over the same roads in the same trucks at the test site, put into the same type of air tight barrels for the same length of time, etc. The one variable was the degree of radiation exposure. To some tax-payers it may seem like an unnecessary expense to provide the control mice with a free ride to the Pacific, but, of course, this was essential to the success of the experiments.

AVERAGES

There is little doubt that measures of central tendency—the mean and the median—are most useful tools in the statistical treatment of data. In fact, we have come to accept their use so spontaneously that sometimes we fail to recognize that they may have limitations—like the man who drowned attempting to cross a river which had an average depth of three feet.

During an AEC operation a group of men at the site were exposed to levels of radiation greater than normal. Actually, the radiation dose received by any of the men was not dangerous, but since this was not known at the time by the cognizant office at another geographic location, a request was made for information. The reply stated that the average dose for all of the men was so much. Now, this might have had some statistical significance, but actually it failed to supply the needed information. This was a case where wide variance in doses received was possible, and the concern was for the health of each and every individual, not an average for all.

INTERPRETATION OF THE SPOKEN OR WRITTEN WORD

Often loose speaking or writing stems from loose thinking or may be conducive to loose thinking.

How often has one heard the expression, "That is not far from wrong," when actually what is meant is ". . . not far from right."

I recall sometime ago attempting to hurry my young son through the ordeal of washing his hands before dinner. He had reached the stage of covering his hands with soap (and covering the cake of soap with dirt) and was happily squishing the suds through his fingers when I impatiently told him to wash off the soap and come to the table. Very dutifully he picked the cake of soap out of the dish and washed it off. At the moment, this was not my intent, but certainly it could be construed to be so from my statement.

In transporting certain quantities of radioactive materials, a label is placed on the container to the effect "No person shall remain within three feet of this container unnecessarily." The basic reasoning here is that, whereas the radiation level is not dangerously high, it is undesirable for one to remain in close proximity for long periods of time. This would result in the accumulation of a radiation dose which, while not hazardous, is an unnecessary exposure. There is no restriction to approach the container for short periods of time; in fact, the containers are handled directly, and not by any remote control equipment.

In one shipment of similar quantities of radioactive material, a hand-made label was placed on a container "Danger—do not approach within 10 feet." The intent of the label was the same as the first one, but did it convey the same meaning? In this case, some men refused to move the packages while others who did handle them were apprehensive later as to possible injury they might have incurred. They liken the

directions on the label to that of a fire where a close approach, even for a short period of time, could be hazardous.

There are times when all of the possibilities of meaning are not appreciated because one stops too soon in his analysis or does not examine closely the statements made. An oft-told story is the difference between an optimist and a pessimist in that one says that the glass is half full and the other says the glass is half empty. The usual assumption probably is that it is the optimist who says the glass is half full and the pessimist who says it is half empty. However, one could postulate that the glass contained a material such as caster oil. Further, the point of view would depend upon whether the caster oil were to be taken internally or to be used as a lubricant. Even if it had to be taken internally, it may not necessarily be a pessimistic point of view to say the glass is half full, since it is conceivable that this amount or more might be desirable under some circumstances.

CAUSE-EFFECT RELATIONSHIP

One of the most fundamental, and often difficult, operations in research is the establishing of relationships between sets of data. Of these, cause-effect relationships are especially important.

The question has been raised as to the causal relationship between the nuclear detonations that have taken place and the appearance of tornadoes. There is an unmistakable, positive correlation between the increased number of nuclear detonations and the increased number of reported tornadoes in the United States since 1950 but does this signify a cause-effect relationship? Without going into a technical meteorological discussion, some interesting information has come to light as a result of studies of this phenomenon.

A tornado or any wind storm must be reported to the U. S. Weather Bureau before it may be put on the record.* It must be observed in sufficient detail to permit identification as a tornado, or it must do damage that can be recognized as being characteristically due to a tornado. Since past experience indicates that all tornadoes are not reported, it would seem a likely hypothesis that the percentage of tornadoes reported should increase as the population increases and should be higher in regions of higher density populations.

A plot of the population increases during the past thirty years in the United States and of the increased number of tornadoes reported show remarkably similar trends. In fact, one might readily postulate that growth in population is an adequate explanation for the increase in numbers of reported tornadoes.

A statistical treatment was applied to the data obtained from 28 regions where analysis was made of the frequency of tornadoes and density population. The test of significance was less than 0.04 and possibly less than 0.001.

Further examination showed (a) the number of tornadoes reported in the United States was below normal for 1945 and 1946—the first two years of nuclear detonations, (b) in 1952 and 1953 the onset of tornado activities *preceded* the first test detonations, (c) starting in 1951 the sharp rise in number of tornadoes reported coincides with the initiating of a program by the U. S. Weather Bureau for an improved reporting system including the subscription to a press clipping service for this purpose.

Due to the above factors influencing the total number of tornadoes reported each 12 months in successive years, it would seem appropriate to compare trends for a given month from year to year, with trends for other months. This analysis indicates that for those months of the year when nuclear detonations have occurred, the proportionate increase in reported tornadoes is somewhat less than for other months. Thus, one could jump to the conclusion that nuclear detonations *inhibit* the formation of tornadoes. However, the best estimate of all

* Appreciation is expressed to D. Lee Harris of the U. S. Weather Bureau for the data that follows.

the available data, including others not described here, is that there has been established no cause-effect relationship between nuclear detonations and the appearance of tornadoes.

ASSUMPTIONS

Oftentimes there are inadequate data available to allow drawing firm conclusions. It may not be simply a matter of gathering more data in a hurry, but rather of making the best estimate based on whatever information is at hand. This may require making simplifying assumptions. In fact, the use of assumptions, directly or implied, is so common that it behooves us to be aware that any conclusion is only as valid as the assumptions upon which it is based.

There certainly is nothing inherently incorrect about the use of assumptions. Quite the contrary, they are a most powerful means of developing concepts. It is a good mind that can postulate assumptions, conceive of the pathway that they will lead into and evaluate the conclusions in the light of the stated assumptions. Likewise, it takes an objective mind to postulate assumptions without bias of personal feelings, to follow wherever they may lead, and to accept the conclusions that may be distasteful to the individual.

I recall a rather heated discussion over a report that had been prepared by scientist A. It was being challenged by scientist B. The conversation went something like this:

> Scientist B "This is what you think!"
> Scientist A "No, that isn't even what I said I think. I say, if you take certain assumptions and calculate on the basis of these assumptions, what happens is you come out with these answers."

I think this illustrates nicely not only the role of assumptions but also the objectivity that should be employed to realize the greatest benefits from their use.

In looking back over the past four years with the Atomic Energy Commission, I have tried to think what characteristics seemed to be outstanding in the successful pursuit of research. It would be presumptuous of me to attempt an authoritative analysis, but there are two areas that have repeatedly come to my attention. These are difficult to state succinctly, but might be described as follows:

1. Ability to cut through a maze of information to see what the fundamental problem actually is; to see what parameters are involved and what data or avenues of research are needed to supply the basis for further appraisal. It has not been unusual to have spent considerable time in discussing an issue over and over and finally to have someone really get to the "heart of the problem" by a stroke of insight. Then would begin the job of mapping out what further efforts were needed to reach a solution.

2. Ability to identify the many relevant variables in a problem and to make reasonable estimates of how each may affect the conclusion. This requires not only a sound knowledge of the pertinent facts, but also an appreciation of what is missing—what variables may be in operation that are not immediately apparent. Further, the ability to make estimates of how those variables may influence the conclusion, I have found, is very common to problems. The usual evaluation, at least intially, requires qualitative or semi-qualitative estimates. I think this aspect should be emphasized before this meeting of science educators. In addition to educating students in precise mathematical solutions of problems, much effort should be devoted to helping him in developing the ability to make reasonable estimates, often based on limited data, of the direction and order of magnitude that the variable may have in influencing the answer. We rightfully frown upon a student introducing "fudge factors" in his laboratory experiments but perhaps this might reveal relationships of the variables that he would fail to otherwise note. This is not a recommended procedure for the student but the general idea is well worth considering as a teaching method.

THE ROLE OF ASSUMPTIONS IN NINTH-GRADE GENERAL SCIENCE *

Ellsworth S. Obourn

U. S. Office of Education, Department of Health, Education, and Welfare, Washington, D. C.

The Problem and its Background

The purpose of this investigation was twofold:

(1) To determine the assumptions which may be supplemental to the observational data, but which are essential to the acceptance of conclusions to be reached in a selected group of experimental exercises in ninth-grade general science.

(2) To study ways in which a selected group of teachers of ninth-grade general science make provision for these assumptions in their teaching procedures.

Much of the so-called experimental work in general science is devoted to the illustration of principles or their application. There is, in most cases, little thought given to the basic essentials of good experimental technique involving such elements as the formulation of hypotheses, the collection and evaluation of evidence, the setting of controls, the identification of variables, the testing of hypotheses and the identification and evaluation of assumptions which are basic to the acceptance of conclusions.

It was the considered opinion of the investigator after more than a quarter of a century spent as a classroom teacher of general science, that the abilities involved in the recognition and evaluation of assumptions were an important aspect of adjustment to present day living. If this hypothesis may be considered tenable then the abilities involved in the recognition and evaluation of assumptions should have considerable emphasis in the training of young people. Many of the ideas that we accept as truth are based in part, at least, upon assumptions that are often implied but seldom stated. For intelligent adjustment to present day living, it would seem reasonable to believe that young people should learn to recognize and evaluate the assumptions, implied or stated, that underlie so many of the conclusions they are called upon to accept in their everyday contacts.

A preliminary study by the investigator revealed that the word "assumption" did not appear in fifty general science textbooks published during the last decade. A further study of general science textbooks, laboratory manuals, and workbooks gave no evidence of provisions for the identification nor the evaluation of assumptions in the experimental exercises. These results made it clear that some investigation of the problem of assumptions was in order.

The General Procedure

Thirteen sources of experimental exercises were selected from textbooks, workbooks, and laboratory manuals of ninth-grade general science.

All experimental exercises in each of the sources were tabulated. This resulted in a total of 1,066 such exercises. From this group 45 exercises were selected for intensive study.

The 45 experimental exercises selected were subjected to intensive analysis by the investigator and a competent jury of three members for the purpose of identifying the assumptions in each exercise which were basic to the acceptance of the stated conclusions. These analyses resulted in the identification of 212 original assumptions.

Following is a typical experimental ex-

* Based on thesis entitled "An Experimental Investigation of the Assumptions Underlying Selected Experimental Exercises in Ninth-Grade General Science and the Ways in Which Teachers Make Provision for Them," submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, New York University. Paper presented at the Twenty-Sixth Annual Meeting of the National Association for Research in Science Teaching, Chalfonte-Haddon Hall, Atlantic City, New Jersey, February 16, 1953.

ercise including the stated purpose, the directions, the conclusions to be reached and the assumptions which were identified as necessary to the acceptance of the conclusion.

Title

The Elements of a Fertile Soil

Purpose

To determine if some kinds of soil bacteria help plants grow.

Directions

Secure two pots of soil from a field in which crops of clover or beans are growing. Heat the soil from one pot to 130° F., and keep it at that temperature for 20 minutes in order to kill the bacteria in the soil. Then plant in each pot some seeds of clover and beans. Keep both pots well watered and in a good growing light and temperature. When the young plants are one month old remove the soil from the roots and determine any differences in root conditions. Also observe any other differences in the plants from the two pots.

Conclusion

Some kinds of soil bacteria aid the growth of plants. (Taken from the Teachers Manual.)

Assumptions

The acceptance of the above conclusion rests upon certain things that are taken for granted as true. (Assumptions.)

1. The soil in which clover and bean plants grow contains bacteria which aid the growth of plants.
2. Heating to 130° F., and maintaining this temperature for 20 minutes kill the bacteria.
3. Soil bacteria are the sole cause of observed differences in growth and root structure.
4. The seeds used in each pot had the same rate of germination.
5. Clover and bean seeds will germinate and their plants will grow in soil that has been heated to 130° F.
6. One month is sufficient time to cause a difference in growth and root structure in the experimental and control pots.
7. A temperature of 130° F., maintained for 20 minutes does not alter any other materials in the soil which might aid the growth of plants.

Three juries designated as A, B, and C each made up of seven groups of four jurors each were selected as follows:

(1) Jury A was comprised of recognized leaders in the field of science education.

(2) Jury B was comprised of recognized leaders in the field of science education who had demonstrated some contact with the problem solving objective.

(3) Jury C was comprised of a highly selected group of teachers of ninth-grade general science.

The purpose, directions, conclusions and identified assumptions for each of the 45 experimental exercises were duplicated and assembled into booklets of nine exercises each. These booklets were submitted to various groups of the above named juries. Each individual juror rated the assumptions on nine experimental exercises as *essential* or *unessential* to the acceptance of the stated conclusion, and added any assumptions which were deemed essential and which had not been included in the original list. These ratings added 188 essential assumptions. This made a total of 412 assumptions identified with the 45 experimental exercises.

In a check of the reliability of the original data secured from the three juries it was found that 16 per cent of the original jurors, reevaluating 84 per cent of the original assumptions, from 75 per cent of the experimental exercises, had an overall consistency of 82 per cent.

The 45 experimental exercises and the 412 assumptions were submitted to careful analysis by the investigator and a competent jury of experts. The analyses were repeated after a lapse of six months time and again after a second period of four months. The first repetition resulted in a consistency of 97 per cent and the second in a consistency of 95 per cent. As a result of these studies the 45 experimental exercises were classified into the following types:

(1) Exercises dealing with Causation
(2) Exercises dealing with Effect
(3) Exercises dealing with Property
(4) Exercises dealing with Condition
(5) Exercises dealing with Procedure

The 412 assumptions were organized into the following categories:

(1) Assumptions of Cause
(2) Assumptions of Effect
(3) Assumptions of Property
(4) Assumptions of Condition
(5) Assumptions of Procedure
(6) Assumptions of Principle
(7) Assumptions of Meaning
(8) Assumptions of Source

An index of agreement for each of the three juries on each of the 412 assumptions was determined by finding the percentage

of cases in which the assumption was rated as *essential*. By a similar procedure a combined index of agreement for all juries was determined for each assumption.

The second purpose of this investigation was concerned with securing evidence on the ways in which teachers make provision for assumptions. This was done by classroom observation. Eleven cooperating centres were selected where science teachers were being trained. This selection was made from an original group of 21 institutions.

A Manual for Observers was written to prepare observers for making directed observations. The plan called for observers to go into classrooms where experimental exercises were being taught and secure evidence on the extent to which, and the ways in which, provision was made for assumptions. Following the observations, anecdotal reports were written according to a pattern prescribed in the Manual. These reports were returned to the investigator for analysis and interpretation. Usable reports of 100 observations of the teaching of experimental exercises in ninth-grade general science were thus obtained.

The Evidence—Part I

The average mean Index of agreement on the essentiality for all categories of assumptions was found to be 71. Jury C, made up of selected teachers of ninth-grade general science had the consistently highest index of agreement; Jury A, made up of leaders in the field of science education was next; and Jury B, made up of leaders in science education who had made some contribution to the field of problem solving, had the consistently lowest index of agreement. The percentage of cases in which juries showed a tendency to agree as often as to disagree on the essentiality of an assumption was very small. It was found that on the average Jury B had a greater tendency to agree with Jury A than with Jury C. There was considerable presumptive evidence to show that Jury B was the most critical of all the juries.

Forty per cent of the assumptions were found to have mean indices of agreement that were above 80 or below 50, and sixty per cent of the assumptions had indices of agreement between 50 and 90. The data revealed that Jury C was in complete agreement on the essentiality of assumptions in 45 per cent of the cases, Jury A in 28 per cent, and Jury B in 24 per cent.

The mean index of agreement for assumptions associated with each of the five types of experimental exercises was determined. The average of these mean indices was found to be 71.

The influence of certain elements concerned with the logical pattern of an experimental exercise in the judgment of juries on the essentiality of assumptions was closely studied.

An analysis of both the original and the added assumptions was made by category on the basis of those which were factual and those which contained an element of reasonable doubt (non-factual). This analysis seemed to reveal rather sharp differences between factual and non-factual assumptions in the original and added groups. The mean index of agreement for each jury on both factual and non-factual assumptions was determined. These data indicated that among the personnel associated with this study there seemed to be a greater sensitivity toward assumptions that were factual than toward those which contained an element of reasonable doubt.

The Evidence—Part II

One hundred classroom observations of experimental exercises in ninth-grade general science were studied. Sixty-three per cent of these exercises were identical with the 45 experimental exercises selected for study in Part I. These observed experimental exercises were typical, both with respect to type of exercise and the categories of assumptions associated with them, when compared with the type of experimental exercises and their associated assumptions, selected for study in Part I. A total of 138 assumptions were identified

in the observed experimental exercises. Fifty-five per cent of these assumptions were classified as factual and 45 per cent as non-factual.

Physical factors of the school environment such as type of community, school population, and size of class appeared to have no influence on the provision of classroom situations related to developing the abilities associated with assumptions. On the other hand there was evidence to show that assumptions are more likely to be provided for in experimental exercises when some provision has been made for other aspect of problem solving, such as the use of control factors, proposing hypotheses, and the analysis and interpretation of data.

For the most part experimental exercises in ninth-grade general science as revealed by this study, are presented by the teacher demonstration method. Teachers appear to have adequate manipulative techniques but in general, rate very poorly in experimental techniques where control factors are used, hypotheses are proposed, and data are analyzed and interpreted.

The data revealed that the devices most frequently used by teachers in identifying assumptions were questioning and discussion.

The Conclusions

Within the limitations of the general procedure and the specific techniques used in this study the following conclusions seem reasonable:

(1) There is preponderant agreement among writers of general science textbooks, laboratory manuals, and workbooks, regarding the core of experimental exercises which should be included in the course in ninth-grade general science. However, these experimental exercises, as now constituted, are generally inadequate in their provision for the identification and evaluation of the assumptions which are essential to the acceptance of the conclusions to be reached by the experimental exercises.

(2) Juries made up of selected teachers of ninth-grade general science were less critical when evaluating the essentiality of assumptions basic to the acceptance of the conclusions, and associated with the selected experimental exercises used in this investigation, than were juries made up of authorities in the field of science education; and further, these juries of selected ninth-grade general science teachers showed less tendency to agree with juries of science educators on the essentiality of assumptions associated with the experimental exercises in this investigation, than the juries of science educators had to agree with each other.

(3) Factors inherent in the pattern of composition of the experimental exercises selected and used in this investigation such as, having conclusions closely related with the stated purpose and clearly stated directions, influenced the judgment of juries on the essentiality of associated assumptions for the acceptance of conclusions; and further, there is a greater sensitivity on the part of juries involved in this study, for assumptions of fact than for assumptions containing an element of reasonable doubt.

(4) There is a group of assumptions associated with the selected experimental exercises used in this investigation, which may be regarded as essential to the acceptance of the conclusions stated by authors of textbooks, laboratory manuals, and workbooks, of ninth-grade general science and which are to be reached by the performance of the experimental exercises; and further, these experimental exercises contain elements of similarity which enable their classification into types and the associated assumptions contain elements of similarity which enable their classification into categories; however, there is no evidence of a pattern of relationship between the types of experimental exercises and the categories of assumptions.

(5) There is no evidence to indicate that physical factors in the environment of a school operate to select teachers who are more likely to provide learning situations in ninth-grade general science which will

function to promote growth in the abilities associated with the identification and evaluation of assumptions.

(6) Teachers of ninth-grade general science observed in this investigation are not sensitive to assumptions and show little awareness to the role of assumptions in the acceptance of conclusions. This lack on the part of teachers is perhaps a major factor militating against the provision of learning experience in ninth-grade general science which will provide for growth of pupils in the abilities associated with the identification and evaluation of assumptions.

(7) There is a relationship revealed in this investigation between provisions made for practicing other abilities of problem solving in the performance of experimental exercises in ninth-grade general science and provision for the practicing of abilities associated with the identification and evaluation of assumptions.

(8) Experimental exercises in ninth-grade general science, as revealed by this investigation, are presented almost exclusively by the teacher demonstration method. There is evidence to reveal that the manipulative techniques of teachers are adequate and the general experimental techniques which would provide for such elements as control factors, proposing and testing hypotheses, and the analysis and interpretation of data, is appallingly poor.

The Recommendations

(1) There is a need for writers of textbooks, workbooks, laboratory manuals, and courses of study for ninth-grade general science to include in their writings a type of experimental exercise which will conform more to accepted standards of experimental work wherein use is made of control factors.

(2) There is a need for a clearer understanding of the significance and place of assumptions as they are related to the acceptance of conclusions and to the total pattern of problem solving behaviour.

(3) There is a need for the development of classroom techniques which will more adequately provide for training in the abilities that are fundamental to the identification and evaluation of assumptions.

(4) There is need for a group of learning studies at various levels of science instruction which will attempt to evaluate the worth of experimental exercises designed to conform more to accepted standards of experimental procedures as compared with the present types of exercises, in their provision for the identification and evaluation of assumptions which are basic to the acceptance of conclusions.

(5) There is a need for a group of learning studies which will evaluate new techniques designed to provide training in the identification and evaluation of basic assumptions, as against presently accepted techniques.

(6) There is a need for the development of a greater awareness on the part of science teachers and administrators, through whatever channels may be available and suitable, to the vital importance of assumptions in the day to day thinking of the man in the street, to the end that this awareness may lead to greater teaching emphasis on the abilities involved.

(7) There is a need to include in the program of studies for prospective teachers of science, procedures designed to make them more sensitive to the place of assumptions in the acceptance of conclusions; and a further need to include in the program of studies for prospective teachers of science abundant experience which will give training in the abilities involved in the identification and evaluation of assumptions.

(8) There is a need for a group of learning studies which will investigate more closely the relationships which appear to exist between provision for various elements of problem solving in experimental exercises in general science.

(9) There is an acute need for some type of inservice training for present teachers of ninth-grade general science to make them more sensitive to the identification of assumptions and more aware of the role of assumptions in the acceptance of conclusions.

THE RELATIVE EFFICIENCY OF READING AND DEMONSTRATION METHODS OF INSTRUCTION IN DEVELOPING SCIENTIFIC UNDERSTANDINGS * †

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THE PROBLEM

The teacher demonstration method of instruction is commonly employed in science classes at all grade levels. Where this method is supplemented by discussion, reading, and the opportunity for individual laboratory experimentation, few science teachers would dispute its effectiveness in promoting the formation of understandings on the part of students. There is evidence to support laboratory experimentation if the teacher wishes to really promote *learning and doing* science rather than *learning about* science. There is evidence to support the use of an *inductive* approach to science instruction if one wishes to develop the ability to use the methods of science with accompanying scientific attitudes. The use of a combination of all of these constitutes sound science instruction.

However, it is recognized that there are pupils enrolled in science courses who belong there in spite of their low level of reading ability and the lack of suitable reading materials relating to the content to be taught—materials adapted to their reading ability. It is also recognized that classroom demonstration apparatus is not always available or may be impracticable for use in certain situations. To what extent can demonstration without reading be used in science instruction when it is necessary to teach in this manner? Similarly, to what extent can reading without concrete experiences or illustration be used when it is necessary to so teach?

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† Financed by Graduate School Research Grants, University of Minnesota.

Aside from the practical phase of the problem, which is the one of interest here, there is the pure scientific or psychological problem of the direct and joint contributions of reading, demonstration and individual experimentation to the formation of scientific or psychological concepts.

The purpose of this study was to compare the efficiency of three methods of instruction for developing understandings in ninth grade general science. Specifically, the study compared the achievement of general science pupils (1) who read and discussed prepared materials, (2) who did no reading but were given demonstrations with discussion over the same material, and (3) who were taught by a combination of these methods. Time required was four class periods for instruction, plus two additional class periods for testing. A retention test was given after a period of 3–10 weeks. The subject matter dealt with mirrors and mirror images. Since these concepts were not usually introduced at the ninth grade level, it was assumed that they were similarly new for most students.

The three methods of instruction were defined as follows:

Reading Approach. Students were given a 6-page mimeographed pamphlet on mirrors as the basic instructional tool. This instructional booklet was prepared by the author and contained no pictures, diagrams, or concrete illustrations. Each student was also given a study guide and instructed to secure for himself the answers to as many questions as possible during the assigned reading periods. Approximately one-half of each 50 minutes period was devoted to this activity. The remainder of time was spent in verbal discussion of the reading

material. At no time were demonstrations or diagrams employed for instructional purposes. No other reading material was available. All study took place during the class periods and no study materials were allowed to leave the classrooms.

Demonstration Approach. Teachers were asked to make extensive use of demonstrations, diagrams, and concrete illustrations as teaching aids. No reading material, including textbooks, was given to the students. Through discussion of demonstration results, students sought answers to questions listed on a guide sheet.

Combination Approach. In classes instructed by the combination method, reading material (mimeographed), demonstrations, concrete illustrations, and diagrams were all freely used. Demonstrations sometimes followed and sometimes preceded the reading material. This approach represented the more usual or typical method of instruction, whereas the reading and demonstration approaches represented a theoretical rather than a practical contrast. The latter two methods were deliberately designed in this fashion so as to increase the likelihood that overall significant differences would be found.

The eight teachers who participated in the experiment were instructed by the author in the proper application of the experimental treatments and the use of the measuring instruments. This instructional period was approximately three hours in length including time for discussion and questions by the participating teachers. In addition, all participants were presented with instructional sheets which described the experimental procedures in some detail.

THE POPULATION AND SAMPLE

The population was defined as consisting of ninth grade science pupils of both sexes enrolled in the public schools of St. Paul, Minnesota during the school year of 1953–54. Twelve public schools in St. Paul offered courses in ninth grade general science. Teachers of these courses were contacted by mail, and asked to participate in the experiment. Affirmative replies were received from eight teachers representing a total of 16 science classes. These 16 classes were assumed to be a representative sample of ninth grade science classes in the St. Paul Public schools. However, the conclusions are restrictive to the schools included in the experiment.

MEASURING INSTRUMENTS

The tests employed in this study were developed the previous year at University High School. Administration in this study was to all classes at the close of the experimental period and as a retest after an eight week time lapse.

(a) *50-item (multiple choice) achievement test.* This test covered mirrors and mirror images. When previously administered to three ninth grade science classes at University High School, the reliability (Hoyt) was found to be .836, and the average item difficulty 43.7 per cent. A high proportion of items were found to be significant discriminators at the one per cent and five per cent levels of probability. This examination was not administered as a pretest since pilot studies had shown that it was too difficult to be of value when used for this purpose.

(b) *32-item performance test (nonverbal).* This test required students to identify and characterize various images formed by plane, convex, and concave mirrors. A complete item analysis was also available on this test based on results for University High School. This test was also found to be satisfactory in terms of reliability, .864; average difficulty, 38 per cent; and item discriminating power.

(c) *Attitude scale.* Apart from the measuring instruments described above, the attitudes of individual members of each class were investigated with respect to method of instruction. Twenty statements relating to the conduct and social climate of the class were presented to each student with instructions to make a plus sign before

the statement to indicate agreement; a minus sign to indicate disagreement; and a 0 to indicate indecision.

In addition to the three measures obtained at the close of the experimental period, intelligence scores and reading scores were obtained for control purposes. The intelligence scores were secured from the Otis Self-Administering Test of Mental Ability. The majority of reading scores were obtained from the Stanford Achievement Test, although some were obtained from the Iowa Every Pupils Test of Educational Development.

STATISTICAL ANALYSIS OF THE DATA

In this experiment it was impracticable to administer different treatments simultaneously to different members of the same class, and it was not possible to reorganize classes according to the criterion of randomness. For these reasons, classes were treated as a unit, and randomness was introduced by assigning the three treatments at random to the 16 classes with the following restrictions:

(a) No teacher taught the same method twice, and
(b) The three treatments were replicated the same number of times.

Unweighted means were used as a measure of effectiveness of the treatments rather than weighted means, since it was desirable to give each class the same weight in the analysis.

Analysis of Variance with One Classification

All 16 sections were employed in this analysis in which the principal statistical technique was the analysis of variance. An assumption underlying the use of this technique was homogeneity of variance among the three treatments. This assumption was tested by use of the L test, and was accepted in every case. Another assumption underlying the use of this technique is reasonable normality of test data. The scores obtained by administering the three tests to the entire population in this study were tabulated with frequency distributions and plotted on normal probability paper. All three lines were approximately straight indicating normality of test data on all three tests.

Mean scores for each variable under each method of instruction are shown in Table I. From this table it may be seen that performance on the final achievement tests was nearly the same from method to method. Similarly, differences between mean retest scores were very small. The only variable showing a large difference in this respect was the attitude scale, where the reading method of instruction was clearly regarded with least favor. Some differences were noted in mean I.Q. scores of pupils instructed under the different methods.

The hypothesis of equal treatment means was accepted for both final achievement tests, the objective and the practical. Also,

ANALYSIS OF VARIANCE TABLES
STUDY ON DEVELOPMENT OF UNDERSTANDINGS IN NINTH GRADE GENERAL SCIENCE
St. PAUL, MINNESOTA, 1953–54

TABLE I

MEAN SCORES UNDER THE THREE METHODS OF INSTRUCTION FOR SCIENCE CLASSES UNDER EACH METHOD

	Reading	Demonstration	Combination
Multiple-Choice final	20.00	21.66	20.31
Practical final	14.90	16.21	15.60
Attitude scale	1.37	7.75	7.50
Multiple-Choice retest	17.95	18.53	17.91
I.Q. (Otis)	105.66	103.92	98.91

no differences between treatment means on these variables were found when intelligence scores were controlled by the analysis of covariance. When classes were retested on the multiple-choice examination, differences again were nonsignificant. These results were in substantial agreement with the pilot studies where it was found that the contrasting treatments appeared to have little or no effect upon the same variables.

Significant differences between treatment means were found, however, using results of the attitude scale. Clearly the reading method of instruction was regarded with least favor. Since the experiments were of comparatively short duration, differences in attitudes probably did not exert maximum influence on treatment means. All of the above analyses are summarized in Tables II, III, and IV.

Analysis of Variance with Three Classifications

This portion of the analysis was designed to remove the effects of certain other factors from treatment comparisons. For this purpose, data were utilized from three science teachers who had taught all three experimental methods. Students in each class were stratified into an upper, middle, and lower group based on performance on the reading examinations. Means for each group are given in Table V.

A three-way analysis of variance using unweighted means was an appropriate model upon which to analyze the results.[1] This analysis provided a test for each of three main effects:

[1] Lindquist, E. F. *Design and Analysis of Experiments in Psychology and Education*, Boston: Houghton Mifflin, 1953; 393 pp.

TABLE II

ANALYSIS OF VARIANCE AND COVARIANCE OF MULTIPLE-CHOICE FINAL EXAMINATION WITH I.Q. HELD CONSTANT

Source of Variation	D.F.	Adjusted or Reduced Sum of Squares	Adjusted or Reduced Mean Square	F	Hypothesis
Between methods	2	40.6176	20.3088	1.795	Accepted
Within methods	12	135.7920	11.3160		
Total	14	176.4096			

TABLE III

ANAYLSIS OF VARIANCE AND COVARIANCE OF PRACTICAL EXAMINATION WITH I.Q. HELD CONSTANT

Source of Variation	D.F.	Adjusted or Reduced Sum of Squares	Adjusted or Reduced Mean Square	F	Hypothesis
Between methods	2	14.6552	7.3276	1.1664	Accepted
Within methods	12	75.3884	6.2823		
Total	14	90.0436			

TABLE IV

ANALYSIS OF VARIANCE OF ATTITUDE SCORES FOR THE SIXTEEN SCIENCE CLASSES IN ST. PAUL

Source of Variation	D.F.	Adjusted or Reduced Sum of Squares	Adjusted or Reduced Mean Square	F	Hypothesis
Between methods	2	130.2630	65.1315	10.1361	Rejected *
Within methods	13	83.5337	6.4257		
Total	15	213.7967			

* $P < .01$.

TABLE V

MEANS ON THE EXPERIMENTAL VARIABLES BY METHOD AND TEACHER IN THE ST. PAUL STUDY

	Teacher A			Teacher B			Teacher C		
	Method R	Method D	Method C	Method R	Method D	Method C	Method R	Method D	Method C
Multiple-choice final	23.00	28.75	29.21	16.82	18.44	20.00	19.19	17.84	18.10
Practical final	16.50	19.88	19.43	8.33	15.56	11.80	15.70	13.42	16.75
I.Q. (Otis)	112.75	104.12	104.75	98.00	100.88	94.60	101.34	98.16	101.22
Multiple-choice retest	21.00	26.16	27.72	16.00	14.22	18.41	17.63	15.64	15.93

(a) method of instruction
(b) teachers
(c) reading level

A test was also obtained for each of three first order interactions:

(a) methods and teacher (MT.)
(b) methods and reading levels (ML.)
(c) teachers and reading levels (TL.)

With this design it was possible to investigate the possibility that teachers were more effective with certain methods, or that methods of instruction were more effective at certain levels of reading ability. The one second-order interaction of methods, reading levels and teachers (MTL) was used as an estimate of σ^2, the population variance. This provided a valid estimate of experimental error since groups within treatments were randomly assigned. A limitation of the design was found in the small number of degrees of freedom available for each test. Under these conditions, differences would have to be quite large if they were to be detected. The alternative was to assume, contrary to fact, that pupils were randomly assigned to each class. (Analyses conducted under this assumption failed to disprove any experiméntal conclusions.)

An analysis of variance was carried out for the two final examinations. In each analysis two main effects were significant: differences between teachers, 5% level, and differences between reading levels, 1% level. Also, interaction between teachers and methods was significant on the practical examination, 1% level. Teachers were not found to be equally effective with all three methods of instruction. Differences between the three methods of instruction, the reading method, the demonstration method, and the combination method were nonsignificant. This was in agreement with the previous analysis made on all sixteen sections using a one-classification analysis of variance. An interesting result was that variation due to teachers was greater than the combined variation of all other main effects and interactions. This was the analysis which permitted the isolation of a teacher effect. It indicated in this investigation that teachers exerted greater influence over achievement than did methods of instruction.

Results of the multiple-choice achievement test were further analyzed holding I.Q. score constant. When the subgroups were made comparable with respect to I.Q., the only change was in the variation due to reading levels, which was no longer significant. Variation between teachers remained as the significant and principle contributor to experimental variation. The analysis is summarized in Table VI. No change was observed in retest results on the multiple-choice examination. This indicated that students could retain information equally well under the three methods of instruction.

CONCLUSIONS AND IMPLICATIONS

It may be seen that within the experimental procedures outlined in this report, reading and demonstration methods of instruction were equally effective in promoting the learning of scientific principles. This was true whether learning was measured by a verbal or by a performance test.

However, in the study which made some attempt to ascertain attitudes of students

TABLE VI

ANALYSIS OF VARIANCE AND COVARIANCE OF MULTIPLE-CHOICE AQHIEVEMENT EXAMINATION HOLDING I.Q. CONSTANT

Source of Variation	D.F.	Σx^2	Σy^2	Σxy	D.F.	$\Sigma x^{2'}$	M.S.	F	Hypothesis
Total$_1$	12	131.46	276.70	— 27.80	11	127.67			
Error (TML)	8	55.59	199.0	— 40.5	7	47.35	6.764		
TM·	4	75.87	77.7	12.7	4	80.32	20.080	2.969	Accepted
Total$_2$	12	107.82	352.80	20.70	11	106.61			
T·L	4	52.23	153.8	19.8	4	59.26	14.815	2.190	Accepted
Total$_3$	12	68.56	374.70	— 64.40	11	57.49			
·ML	4	12.97	175.7	— 23.9	4	10.14	2.535		Accepted
Residual	20	196.66	606.20	— 31.90	19	194.98	10.262		
T	2	648.16	415.5	512.3	2	423.96	11.980	20.657	Rejected *
Total$_4$	22	844.82	1021.70	480.40	21	618.94			
M	2	27.16	64.8	— 35.7	2	22.03	11.015	1.073	Accepted
Total$_5$	22	223.82	671.00	— 67.60	21	217.01			
L	2	62.74	2024.6	349.3	2	26.13	13.065	1.273	Accepted
Total$_6$	22	259.40	2639.80	317.40	21	221.11			

* $P < .01$.

where $T = 1, 2, 3$, Teachers
$M = 1, 2, 3$, Methods
$L = 1, 2, 3$, Reading Levels

toward their method of instruction, the demonstration method was regarded with most favor. Since the experiment covered little more than a week's time, differences in attitudes probably did not exert their maximum influence upon achievement. It would appear useful in the future to investigate reading and demonstration methods of instruction over an extended period of time.

A further question of interest concerns the appropriateness of the instructional methods for different levels of intellectual ability. The interaction between intelligence level and method of instruction could not be tested in any of the experiments. However, a similar interaction (reading level and method) was insignificant in the experiment when this interaction was tested. This problem is a crucial one in individual differences and it is recommended that it be examined in future investigation. It would also seem desirable to design future experiments in such a manner that variation due to differences between teachers could be isolated. Perhaps this cause of variation which often has been overlooked in educational experiments may prove greater than variation due to differences between these and similar methods.

Finally, it would be informative to make similar treatment comparisons using other sets of scientific principles. Appropriate reading materials may sometimes be difficult to obtain or ill-adapted for use at the junior and senior high school levels. In such cases, it would be useful to know that satisfactory understandings can be developed by use of the demonstration method alone. On the other hand, it would be equally useful to know that the reading approach may be substituted with some confidence in cases where demonstration apparatus is unwieldly or unavailable for classroom purposes.

THE GENERAL EDUCATION SCIENCE PROGRAM AT WESTERN MICHIGAN COLLEGE *

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GENERAL education science programs at the college level, as apart from the types of courses which they include, may be thought of as varying along a gradient from the extreme of a rigidly fixed requirement, under which all students are required to take the same course or courses at a specific point in their college career, to a completely elective situation, in which the general education science courses are provided, but students are free to take them or not, as they wish or as their individual programs dictate. Generally, at the conservative extreme, even students who are science majors or who are pursuing preprofessional science curricula are required to take the courses along with non-science students. At the liberal extreme, on the other hand, preprofessional and major science students are not encouraged, or in some cases are not permitted to take the courses.

Stephens College probably furnishes an example of the liberal extreme.[1] There the General Biology course, which is the principal general education science course, is purely elective, and preprofessional science students are generally not permitted to take it. Michigan State University probably furnishes an example of the conservative extreme, since there all students are required to take the Natural Science course in connection with their work in the Basic College.

Colleges that have general education science programs differ also in the matter of accepting transfer credit from other schools in relation to these programs. Most of them, however, are fairly liberal in this regard, not requiring that the transferred course necessarily be the exact equivalent of their own. This is probably necessary, since most of the better-planned general education science programs are highly localized and vary widely from one institution to another. Some colleges permit students to "comp out" of general education courses, including those in science, by passing comprehensive examinations in the field. These examinations presumably cover the minimal learnings and understandings which are included in the courses, and passing them permits the student to take other courses in lieu of these.

THE WESTERN MICHIGAN COLLEGE PROGRAM AS A WHOLE

The general education program at Western Michigan College stands about midway of the gradient between liberal and conservative extremes as indicated above. It is a flexible program within a rigid general education science requirement. Eight hours of general education science are required as a part of a total of forty-two hours of general education courses. These forty-two hours include, in addition to science, eight hours of social science, six hours of humanities, six or eight hours of communication skills, four hours of physical education, and eight or ten hours elected from a group of courses chosen by the Basic Studies Council, the faculty group which advises the Director of the general education program.

The eight hours of required science may be satisfied by any of four alternatives chosen from among separate general education courses. It should be noted, however, that this is not simply a group elective, under which the student may take eight hours of zoology, or botany, or chemistry, or physics, or geology, utilizing the regular elementary courses in these fields. Rather, in this case, *all* of the courses which may be

* Paper presented at the Twenty-eighth Annual Meeting of the National Association for Research in Science Teaching, Teachers College, Columbia University, April 19, 1955.

[1] The General Biology Course at Stephens College, *Science in General Education*, E. J. McGrath, editor, William C. Brown and Company, Dubuque, Iowa. 1948.

used as alternatives have been built specifically as general education courses, as distinguished from beginning preprofessional and major foundational courses.

The alternatives include the following:

1. Four hours of physical science and four hours of biological science
2. Four hours of biological science and four hours of human geography (earth science)
3. Four hours of human geography (earth science) and four hours of physical science
4. Eight hours (two semesters) of physical science.

The eight to ten hours of general education electives may also consist partly or wholly of science courses, if the student and his counselor so choose. This is a relatively new phase of the program, and the science courses which may be used to fulfill this requirement are not yet well-defined or developed. It is probable that additional work within the already-existing group of sixteen hours of general education science courses may in some cases be used to meet it. It is probable also, however, that as the program is developed, integrating or "cross-cutting" courses at an advanced level will be recognized, modified or developed to fill this need.

Some courses beyond the freshman level which are now available, and which might be used, at least temporarily, in this capacity are Outdoor Science (nature study), Conservation of Natural Resources, History of Chemical Theory, Evolution, General Ecology, Modern Advances in Physical Science, Recent Advances in Biological Science, and Historical Geology. General Psychology, which is offered as a sophomore course, and certain courses in mathematics might also be used in this way.

Indicative of what may be done in the matter of planning specific courses at the advanced level to meet the need for additional general education science electives is a course called The Nature of Science, which is offered by the biology department. This includes intensive study, at the junior-senior level, of scientific attitude and methodology, with some emphasis on illustrations drawn from the field of biology.

Although the general education science requirement at Western Michigan college is rigidly set up to apply to all students, it is recognized that in practice certain exceptions must be made to meet specific situations. Students who enter the college with advanced standing, and who have taken work in science at the other colleges which they have attended, are generally permitted to omit Western's general education science courses, if they have transferred as much as eight hours of science work in two different fields. For this purpose chemistry, physics, biology and the earth sciences are considered as acceptable separate fields.

Students who are majoring or minoring in science, and students who have taken science courses at the freshman level, other than the general education courses, in connection with following specific preprofessional requirements, such as pre-medicine, are permitted to "comp out" of the general education science courses if they can pass comprehensive examinations in them with a grade of "middle C" or better. Such comprehensives, however, must be taken in at least two of the three general education science fields (physical science, biological science, and earth science) in order for the student to be excused from the full eight hours of the requirement. Entering students are also permitted, under certain conditions, to take the comprehensives and "comp out" of the general education science courses on the same basis. They, however, must elect additional courses in science on the advice of their counselor in order to complete their program.

The Basic Studies Council is empowered to grant exceptions to the taking of portions of the general education program in the case of curricula which have as yet not been able to adjust their course load to include all of these courses. This has been done on a temporary basis in a very few cases, but is subject to re-evaluation as the program evolves and matures. Likewise the policies which have been set up to govern exceptions through transfer of science

credit, and exemptions through the taking of comprehensive examinations are tentative. They are subject to re-study and re-evaluation by the Council and the Director of Basic Studies.

THE PHYSICAL SCIENCE ALTERNATIVE

The Physical Science course includes material from the fields of physics, chemistry and astronomy, but uses illustrations from the biological sciences when these are appropriate. Geology and meteorology are not treated in this course because they form a natural part of the subject matter of the earth science course (Human Geography).

Two of the important goals of the course are:

1. To present to students an integrated picture of physical science; to break down compartmentalized thinking. Objects and phenomena in the natural world do not classify themselves into physics, chemistry, biology, and astronomy as such.
2. To present to students as much experiential background with the physical world as possible. Students come to college with very little background in this regard in most cases. They need to expand this.

The course is based on selected principles, grouped around the major principle of the conservation of energy and mass. Conservation of energy is approached through mechanics, and conservation of mass through chemistry. These are then brought together through the study of nuclear energy.

Most of the basic principles are presented during the first semester course, which is repeated for students entering during the second semester. This enables students to use the first semester of the Physical Science course in combination with either Biological Science or Human Geography. For students who elect to complete the general education science requirement with a second semester of Physical Science, applications of principles form the basis of the second course.

The class size is limited to forty. Straight lecturing is de-emphasized in favor of the Socratic method of question and answer. There is no laboratory in the traditional sense, but students are allowed to "handle" as many of the demonstrations as possible, and a problem-solving approach is used consistently. About ten or twelve "home experiments are required of students. The following are examples of these:

1. Each student buys a cheap theromometer. These are bought to class and calibrated against standard temperatures. The Fahrenheit scale is converted to the Centigrade scale, and this is placed on each thermometer.
2. Each student buys a small compass, and is asked to plot the magnetic field around a nail that has been magnetized as compared to one that is unmagnetized.

For each such experiment a data sheet and answers to specific questions are handed in. It is recognized that present procedures are only a "stop-gap" against the time when space and staff facilities will make it possible to introduce more extensive laboratory procedures, and center the course around them.

Heavy use is made of motion pictures, including such films as Encyclopedia Britannica's "Sound Waves and Their Sources," "Fundamentals of Acoustics" and "Molecular Theory of Matter." Relatively few demonstrations are attempted within a single hour class period. It has been found that most students will not absorb more than two or three demonstrations in a single period. It is necessary to delimit carefully the amount of material; to choose a few principles and cover these thoroughly.

THE BIOLOGICAL SCIENCE ALTERNATIVE

This course, which is offered for four hours credit, meets for six clock hours each week during the semester, either three two-hour periods or two three-hour periods. These periods are used for lecture, demonstration, laboratory or field work, as is necessary or desirable according to the nature of the material being dealt with. Actually, between one-third and one-half of the course is laboratory. The units are built around laboratory experiences. Classes are limited to either twenty-four or thirty,

depending on the room in which the section is scheduled.

Biological Science[2] is a block-and-gap course, based on three problem-areas:

1. Nature: A Dynamic Balance
2. Probability: A Factor in Science and Life
3. Disease: A Relationship Between Organisms and Within Organisms

Each of these problem-areas is explored intensively, along with its natural affinities. In this way a fairly wide range of the biological topics which are generally considered important for inclusion in basic biology courses are dealt with. No attempt is made, however, to "cover the field."

Under the first problem-area, dealing with the balance of nature, the following units are included:

a. A Necessary Skill: The Use of the Microscope
b. The Balanced Aquarium: A Community of Plants and Animals
c. The Pond Infusion Culture: A Changing Community
d. Conservation: Man and Environmental Change
e. Evolution: A Result of Environmental Change

Under the second problem-area, dealing with aspects of probability, are the following units:

a. Probability and the Nature of Science
b. Probability in Action: Heredity
c. An Unexpected Aspect of Probability: The Nature and Origin of Life

Under the third problem-area, dealing with disease, are the following:

a. The Body as a Community of Cells: Nonparasitic diseases
b. Invaders from Outside and the Body's Reaction to Them: Parasitic Diseases
c. The Neural Mechanism and Mental Disorders
d. The Mammalian Embryo: A Special Case of Parasitism

The goals of the course include (1) a reaching after fundamental ideas, and (2) an understanding of the point of view of a scientist and the kinds of things that he does. It is possible to isolate within each problem-area one or two large, basic ideas which can be stated as generalizations. These are statements of relationships rather than bare factual statements. Related to these basic ideas are lesser generalizations of a more strictly factual nature, and related to these, in turn, are the "facts of science" at the level of pure subject matter. Facts are used as tools to get at ideas, rather than as ends in themselves.

The centrality of the laboratory prevents this idea-centered course from becoming overly deductive in nature. Scientific attitude and methodology can be taught, if the teaching of them is gone at as specifically as we would approach the teaching of something like the laws of heredity. Therefore a unit on the nature of science is included, along with bringing all other units and experiences to bear on the attainment of this goal. This unit is taught in laboratory fashion, just as the others are. It is placed near the middle of the course because of the need both for subject matter to base it on and time to deal with it adequately.

A danger which is avoided is that of allowing the course to become too classicized. While the value of the historical approach is recognized, and use is made of it within each unit wherever the opportunity arises, the student must not be allowed to fall into the error of thinking that science is something completed, either in the sense of an infallible and universal method, or a finished body of knowledge to be admired and used like a new machine, but no longer offering any real challenges. This is prevented by resorting to a careful and critical utilization of science-in-the-news.

Students are required to read and evaluate a minimum amount of science news each week. They are taught criteria for distinguishing good science news reporting and writing from poor. This regular contact, at the layman's level, with what is new in science gives to students a feeling of being "on the firing line" of advancing research. It is further recognized that science news will be the major contact

[2] "Designing a Basic Science Course for a Specific College Situation," *School Science and Mathematics*, February, 1955.

which the non-technical student will have with research after leaving the general education science program. Also, science news, when it is carefully evaluated, contributes to the achievement of the goal of helping the student to "understand the point of view of a scientist and the kinds of things that he does."

The evaluation of student achievement is carried on by means of structured unit reports and laboratory reports, and tests. These tests are objective "best answer" tests, which stress understanding of relationships rather than memorization of facts. One such test is based on the student's ability to understand and evaluate science news.[3]

THE HUMAN GEOGRAPHY ALTERNATIVE

Human Geography is a non-laboratory course, meeting for four hours a week during a semester for four hours credit. It is organized to emphasize the natural environmental factors to which the activities of people are related. The topics within it are considered on a world-wide basis. The subject matter of the course includes climatology, meteorology, geology, physiography, soil, and the biotic environment. The integrating idea of the course is that of conservation.

The characteristics of the basic climatic types are described, along with their occurrence in the world. Fauna and flora are considered in connection with each climate. Characteristics of land forms, weathering, erosion and soil development are considered under physiography. Rocks and minerals are stressed under geology. Paleontology and evolution are not included here because they form a natural part of the subject matter of the Biological Science course. Ground water and the surface water of the land and oceans are included.

Consideration is given to the effects of climate, soil, minerals, topography and the biotic environment on the occupational pursuits of people, transportation, communication, density of population and the growth of cities. Emphasis is placed on agricultural adjustments in relation to climate. Land use and conservation of natural endowments are stressed. Soil conservation is given a prominent place.

It is hoped that as a result of this course, students will develop a workable picture of the whole earth, with all of its many regions, as the abode of man. As in the case of the Physical Science course, it is recognized that ideally Human Geography should be laboratory-centered. The staff therefore looks forward to the time when, with the necessary expansion of staff personnel and facilities, the addition of laboratory work to the course will be possible.

SUMMARY

The general education science program at Western Michigan College is a broadly permissive one. Through the utilization of its various alternatives it allows a considerable amount of student selection, with adaptation to individual needs and abilities, special curricula and individual programs, all without sacrificing its essential general education character.

It is a program which has not yet reached full development, and probably will never (or should never) become rigidly frozen and fixed. Its staff are still looking for new and better answers to their problems, thereby recognizing that they do not have all such answers yet. In this way the program makes possible, and to some extent even puts a premium on continued research.

Finally, the program emphasizes the laboratory approach, and those in charge of it are not satisfied to accept less on a long term basis. Therefore, the program is being moved in this direction as rapidly as possible. The faculties of each of the alternative areas believe that laboratory work, broadly defined, is just as important for general education students as it is for preprofessional students and science majors.

[3] *A Test of Science Reasoning and Understanding, Form C,* Cooperative Study of Evaluation in General Education of the American Council on Education. Am. Council on Education, 1952.

THE PROBLEM APPROACH IN PHYSICAL SCIENCE *

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Introduction

The past 25 years have seen wide changes in college level science instruction to students not specializing in science. The earlier practice in most institutions was to require them to take one or more of the introductory courses in the separate science departments. But the increasingly technical character of these courses, and the expanding areas in which science was making important discoveries, prompted many college teachers to design other science courses of a different type for these non-specialist students.

The first departures from the traditional courses were made by omitting the more technical material needed only by the specialist and bringing in related subject matter from other areas of science. Thus arose what was called the "survey" course in science in which a student was introduced to concepts and discoveries from several related fields such as astronomy, geology, physics and chemistry, or botany, zoology, physiology, and psychology. He was not only made acquainted with wider portions of the science area but he was shown how many basic principles cut across the artificial boundaries of the separate fields. At the same time he was spared the drill on technical skills which is needed primarily as preparation for advanced work in the different sciences.

But man's accumulated knowledge in science is immense, and is growing at an increasing rate. The temptation to include more and more material in a survey course in science is therefore difficult to resist. By the end of World War II the trend to more subject matter was disturbing general education science teachers at a number of institutions. They were concerned not only with the increased tendency toward superficiality which greater volume of material fosters. They feared that the survey approach was emphasizing almost exclusively the knowledge aspect of science and ignoring another equal or greater aspect, namely, how science gains this knowledge. For students who do not specialize in science, most of the scientific facts they learn will be forgotten, but an appreciation of how science discovers these facts and solves its problems will not only last a longer time but will be of great value to them as future citizens. A variety of ways to restrict the factual content and bring out the methodological aspects of science have been attempted.[1, 2, 3] This paper describes the approach followed for the past ten years at Colgate University.

Core Curriculum in General Education

During the decade of the 1930's Colgate University required all students to take five one-semester survey courses, mostly of four credits each, in physical sciences, biological sciences, social sciences, philosophy and religion, and the fine arts. The first four were located in the freshman year. The virtual displacement of the normal academic program by special courses for naval trainees during 1943–1945 was a natural time to review the curriculum, particularly the requirements for general education. The outcome of this study was the adoption of the following core of required courses designed to extend through the four years.

* Paper presented at the Twenty-Eighth Annual Meeting of the National Association for Research in Science Teaching, Teachers College, Columbia University, April 19, 1955.

[1] E. J. McGrath, Editor, *Science in General Education,* Wm. C. Brown and Company, Dubuque, Iowa, 1948.

[2] I. B. Cohen and Fletcher G. Watson, Editors, *General Education in Science,* Harvard University Press, Cambridge, Massachusetts (1952).

[3] W. C. Van Deventer, *Science Education,* 33, pp. 183–190 (April, 1949); 37, pp. 159–172 (April, 1953).

(There was a language requirement in addition to the core courses.)

Year	Course	Credits
Freshman	Problems in Physical Science	4
	Problems in Biological Science	4
	Problems in Public Affairs	6
	Problems in Philosophy and Religion	6
Sophomore	Area Studies (one of eight)	6
	Communication	3
	Music and the Visual Arts	3
Junior	Literature	3
Senior	American Idea in the Modern World	3
	Total	38

After a few years of experience, a feeling developed in the Faculty that, desirable though these courses might be, the total requirement was too high a fraction of the 120 credits for the B.A. degree, and was too heavily concentrated in the freshman year. Accordingly, in 1954 the core curriculum was revised to the list below, and is progressively being put into effect.

Year	Course	Credits
Freshman	Problems in Physical Science	3
	Problems in Biological Science	3
	Problems in Philosophy and Religion	6
Sophomore	Communication	3
	Music and the Visual Arts	3
	Literature	3
	Area Studies	3
Junior	American Ideals and Institutions [4]	6
Senior	America in the International Community [4]	3
	Total	33

A student may be exempt from any of these courses by passing a special examination. In addition, a student who takes a year laboratory course in any science may omit one of the two core science courses. This provision was adopted, not because of duplication but because it will help a student concentrating in science to obtain a much needed breadth in his program.

[4] Unofficial titles of a 12-credit sequence (with Area Studies) now under development.

Objectives of the Physical Science Course

At the time the core curriculum was launched in 1946, a detailed list of objectives of Core 1, as the physical science course was called, had not been made. The basic plan was to gain greater depth of penetration in limited areas than was achieved in the physical science survey, and also to introduce an emphasis upon how scientific knowledge is arrived at. Hence the suggestion of approaching selected topics as scientific problems seemed eminently suited to the purpose. As experience has been gained with this method, the objectives can now be more clearly stated. They are:

1. To avoid superficiality of approach by exploring the chosen subject matter to greater depth than customary at the freshman level.
2. To introduce actual experience in critical thinking and logical reasoning with science materials.
3. To break the students' habit of relying solely upon the authority of textbook or teacher, replacing it in part by reliance upon the authority of facts and logical reasoning.
4. To convey some understanding of science as an enterprise, as a means of getting knowledge and solving problems.
5. To acquire knowledge in certain areas and an appreciation of the interrelatedness of knowledge in science.
6. To point out some of the relations between science and society, both historical and contemporary.

Obviously there are real limits to the degree of achievement of broad objectives such as these, and there is no easy measure for describing how much is accomplished. But the order in which the objectives are listed indicates the relative importance assigned to them at present.[5]

[5] The companion course, Problems in Biological Science (Core 2), was originally designed for the same purposes in the life sciences. But due to natural differences in staffs and points of view, the present emphases in the two courses are not the same. In Core 2, objective No. 5 would probably appear in the second position with reduced emphasis upon those that follow.

Organization and Conduct of the Course

Colgate University, as a liberal arts college, is committed to the extensive use of small classes and student participation. Accordingly, the two science core courses were set up for three discussion meetings a week of about 25 students each, and one general meeting when all sections came together. With the recent reduction from four to three credits, the total number of meetings per week is now three, with about the same proportion between discussion and general meetings. Most general meetings are lectures in which background material is presented or the line of reasoning of a problem is reviewed. Appropriate demonstrations and films are found valuable if an effort is made to tie them closely to the material being presented. The lecturer is the staff member having the best background in the particular topic.

Staff for these courses is drawn from the regular science departments with occasional assistance from a man in some other area who has adequate background. Each instructor carries his section throughout the entire semester, a policy which may be hard on the instructor at first, but one, it is believed, which is essential for good teacher-student relations and for effective teaching. No instructor is asked to carry more than two sections, equivalent to half his load.

With assorted instructors teaching a course which is different in both subject matter and approach from conventional science courses, certain provisions are needed to prevent too wide a diversity in interpretation of the objectives and standards of performance expected of the students. The most important of these provisions is a weekly staff meeting and coffee hour. Here, in an informal atmosphere, there is a free interchange of ideas, comparing of experiences and discussion of teaching problems. Led by the member who has the best background in the particular area, the staff also takes up the advance material to clear up questions or uncertainties and to plan the broad method of attack to be used. These discussions, particularly if the problem is a target of current research, inevitably bring in advanced information on recent developments. Much of this may be too detailed or difficult for presentation to the students but it serves to enrich an instructor's background and maintain his interest.

Uniformity of standards is achieved by the use of common monthly tests for all sections. All staff members share in the preparation of these tests, with final forms reviewed in staff meetings. Since test questions are so important in setting the objectives of a course as well as its standards, a further discussion of their construction will be found in the section on *Evaluation* below.

Text Materials

No single book can serve as a text for a course of this type, nor is a single source consistent with the objectives of the course. As explained below, when taking up a topic as a scientific problem, the student needs access to factual information as well as certain expository material covering related principles. This material is supplied to the student in two ways. First, he purchases a manual for the course which contains explanations of how each problem will be approached and reproductions of useful articles from sources like the *Scientific American*. The second means is for the student to consult portions of several selected texts or popular books on science. Multiple copies of these are kept on reserve in the library. Experience has shown that some of these library readings are of greater value than others. Those which are largely dogmatic contrast awkwardly with the more investigative attitude which is striven for in the classroom. So they are being replaced with appropriately written exposition in the manual. There is no plan at present to eliminate *all* library readings. The necessity for consulting varied sources has distinct advantages. Students benefit from

differing viewpoints, and they are less likely to regard a single volume as the sole and final authority on all matters.

The Problem Approach

The greatest and most obvious weakness of the problem approach for teaching science in general education to non-specialists is the lack of broad coverage of subject matter. Staff members who taught in the former survey course at Colgate found it quite a wrench to shift to a course which omitted large blocks of material they had thought valuable or important. Obviously, such omissions are justified only if the teacher can bring himself to believe that greater ends can be substituted. He must remember first, that within the span of a one-semester survey course, a great deal of subject matter must be ignored, and second, the retention of factual knowledge in any field is poor unless it is constantly used. He can also take into consideration that most of these students have been exposed, at a lower level of difficulty, to fairly broad science coverage in secondary school general science courses.

There are several advantages to the problem approach. First, for the study of how scientific knowledge is gained, it is a more natural and reasonable procedure than abstract discussions of logic and methodology. Obviously impressed with the tremendous advances in scientific knowledge, philosophers have for years described and analyzed what they call "the scientific method." Many educators have thus taken their cue to summarize into four or five simple steps what this "scientific method" is. Yet research scientists see little resemblance between this summary and their own efforts or those of their predecessors. They claim there is no *single* method for solving all scientific problems; there are many methods. Their position is best illustrated by the colorful and often quoted statement of P. W. Bridgman, Harvard University physicist, who has said, "The scientific method is doing one's damndest with one's brain, no holds barred!" The common factors which appear in all scientific investigations are not steps of procedure, or method, but principles of scientific thinking, such as the requirement that any acceptable hypothesis be consistent with all the available evidence and that such evidence be based upon "publicly verifiable" observations or experiments. If real scientific problems are studied it is possible to bring out frequently the tentativeness of hypotheses, and the bases for their acceptance or rejection, and still note that the procedural steps are far from identical.

A course which discusses scientific procedures and stresses principles of scientific thinking sounds like a course *about* science rather than a course *in* science. This criticism can be avoided with the problem approach because the students can have some active participation in the solutions of the problems. They read about some of the relevant facts and hypotheses proposed and in class discussion they consider the degree of support different facts lend to different hypotheses. This is why discussion meetings are so important for this method of teaching. The educational process of getting the student actually to *participate* in the reasoning process is quite different from the one in which he merely tries to *remember* the steps of reasoning followed by someone else which he hears presented to him in a lecture.

A third advantage of the problem approach is its ability to capitalize upon the natural interest of the student in recent developments. Not every problem currently under investigation lends itself to a course at college freshman level, but there are plenty that are incompletely solved in which students show keen interest. And by selecting problems from a variety of science fields, some breadth is gained by the sampling process, even though the degree of coverage achieved in a survey course is not possible.

Selection of Problems

Although the interest appeal of contemporary scientific problems is obvious, a

person trained in physics or chemistry wonders immediately how it would be possible in a freshman course to deal with problems on nuclear energy levels or the structure of complex organic molecules, where so much background and experience is necessary. Clearly these are out of the question, as are most problems in straight physics or chemistry. But there are many areas in the physical sciences which do not require so much mathematical skill or theoretical knowledge. In geology, astronomy, astrophysics, geophysics, meteorology and the like there are countless problems into the exploration of which these students can be led far enough to appreciate how it is done and what some of the results are, and in the process he learns some basic science as well. A few of such problems are the origin and age of: the solar system, asteroids, meteorites, moon, lunar craters, earth's atmosphere, submarine canyons, Carolina Bays, Pacific atolls, etc., or the cause of climate changes, the stratosphere, ionosphere, aurora, atmospheric electricity, earth's magnetic field, etc. For few if any of these problems will the instructor find source material already prepared for class use. He may have to consult treatises, texts, and scientific journals. Some popular books in science take up these topics and articles in magazines like the *Scientific American* sometimes give good summaries. How far he explores will depend upon the depth of penetration he thinks will interest his students and lie within their capacities. Some of these problems, such as the origin of the solar system, have been the target of investigators for a long enough time that a historical approach to the problem is profitable. In this way the students can see how an appealing hypothesis is later discarded on new evidence or more careful study.

It has been found unwise to use too large a proportion of problems which lack a final answer. Students become uneasy and frustrated if they cannot find some knowledge on which they can rely. One method for treating a "solved" problem is to handle it as a "case history," a method initiated at Harvard University by former President Conant.[6] Since most of the cases are drawn from periods 100–300 years ago, it takes some skill and understanding of the historical setting to make the case histories effective. An alternative method developed at Colgate University is to set up a "solved" problem for which the students may all know the answer, and then enlist student participation to work out the results anew from whatever data and information they find necessary. The students find it difficult not to be influenced by the answer, but it is still possible to engage in a high degree of scientific thinking.

The Problems

Of the problems currently in use in Core 1, three are of the "unsolved" type which are the subject of continuing study. They are:

How did the solar system originate?
What is the interior of the earth like?
What was the origin of the Carolina Bays?

From one and one-half to two weeks is devoted to each of these in the middle of the semester. Two other problems of the "solved" type occupy the remainder of the time. They are:

What is the best explanation for celestial motions?
Why does the temperature of the air decrease as one goes to higher altitudes?

The first of these is one for which the students all know the accepted solution. Its treatment will be described in detail below. None of the students are familiar with the solution for the second of these problems. In the four weeks devoted to it a number of principles of physics are studied relating to hydrostatics, convection, properties of gases, radiation, heat, and kinetic theory. At the end, some application is made to meteorology in the vertical stability of air

[6] James B. Conant, *On Understanding Science*, Yale University Press, New Haven, Conn. (1947). James B. Conant, Editor, *Harvard Case Histories in Experimental Science*, Harvard University Press, Cambridge, Massachusetts (1950, ff.).

masses. Before the credit for the course was reduced from four to three hours, two other problems were included. One, centered on Mendeleyev, studied historically some of the steps in developing our present ideas of atomic structure, and the other sought for the source of nuclear energy released in chain reactions. Both of these fields are tremendous in scope and depth, and to keep the exploratory point of view, there was time to follow the achievement of only certain landmarks in the development.

Problem on Celestial Motions

All entering college students have been given a fairly complete description of the solar system and its motions. But few if any of them would be able to reconstruct it from the available observations. In many general education science courses the history of man's efforts to work out this scheme is studied in some detail. An alternative approach to this subject has been found which enlists more active student participation and does not require such extensive preparation in the history of astronomy on the part of the instructor.

The problem is presented by the question, "Does the earth travel around the sun, or the sun around the earth?" To the student this is no problem. He has been led to believe that all the celestial motions have been worked out by the experts to a high degree of accuracy. The instructor concedes this, pointing out that the student has been deriving his knowledge from an accepted authority, an essential part of education especially at the lower levels. But that is not the way knowledge is originally obtained, he explains. It must be gradually built up and figured out in ways which can seldom be predicted. He then proposes that the students put aside, temporarily, their reliance upon the experts, and endeavor as a class activity, to work out a solution to the question themselves. They may be able to make some of the needed observations directly, though there should be no objection to accepting observations from sources with better equipment and more time, for these observations can be and frequently are independently verified. But all inferences, proposed mechanisms, hypotheses or conclusions derivable from the observations will be made in class and not borrowed from others.

After a preliminary discussion about the sphericity of the earth, the obvious first step is to agree upon what the motions are which need to be explained. Here most students are hazy. To promote the observational attitude they are asked to sketch portions of the night sky and horizon at the four points of the compass, and repeat these sketches from the same vantage point about 30 minutes later. Few sketches turn out accurate, but a synthesis of results for the entire class will show the systematic apparent east-to-west rotation of the entire sky or "celestial sphere" about the earth as a center. To explain this hour-by-hour motion two assumptions or hypotheses can be used. Either the entire sphere is actually revolving around the earth, or the earth is rotating in the opposite sense. The latter idea is less difficult to visualize mechanically but it would be more acceptable if it had the confirmation of some deductive test. A rotation of once a day is hardly enough to make a person dizzy. It might show up, though, in certain situations where moving bodies are partially free of the earth for limited periods. Here the students read about various deflection experiments, and they see a Foucault pendulum change direction in the afternoon lecture. This confirms qualitatively the hypothesis of the rotating earth.

The period of this rotation seems to be about 24 hours. It makes a good laboratory project for some students to determine this time more precisely. On successive nights they can watch and time a bright star disappearing behind the edge of a building when viewed from a fixed location. Their precision may not be high but they are convinced that the period is shorter than 24 hours.

The next step is to consider the left-over motions not fully accounted for by the spin of the earth. The most noticeable is that of the moon (though many city-bred students are ignorant of it) which nightly shifts eastward about 13°, taking 27⅓ days to return to the same position in front of the background stars. On star maps in their manual the students plot several positions of the moon, and current data from the American Ephemeris can also be supplied. It is a natural inference that the moon revolves around the earth once in that period, although no simple confirming test, like the Foucault pendulum, is available.

The sun also shifts relative to the background stars, about one degree a day. This is not directly observable but can be inferred from various observations, such as the 4-minute difference between the periods of sun and stars, or the changing pattern of stars setting after sunset. By analogy with the moon, the hypothesis is proposed that the sun likewise revolves around the earth with a period of one year, in an orbit inclined some 23° to the celestial equator.

Sometimes a clever student suggests that the *earth* should be assumed to revolve around the *sun* once a year instead. A common answer of the instructor is that such a scheme should certainly be investigated, but the student made no such proposal with regard to the moon and it is sensible to follow through the most obvious and plausible hypothesis first.

Attention is next directed to the planets whose motions upon the celestial sphere are not uniform like those of the moon and sun. They progress eastward most of the time but at certain intervals they appear to stop and move westward, then move eastward again. The character of these retrograde loops is made clearer to the students by having them plot the paths on polar coordinate paper. Successive telescopic photographs of Mars and Venus are examined. These show not only large and progressive changes in apparent diameter but phase changes as well. If one discounts the thought that they are pulsating in size, it is evident that they must change their distance from the earth by large amounts. The large thin cresent images of Venus which are seen near the middle of its retrograde motion, together with the fact that Venus never is seen more than 48° from the sun, suggest that Venus is circulating around the sun while the sun is traveling about the earth. A home made model helps to illustrate the arrangement.

A similar scheme for Mars, except that it loops the earth as well, is shown to account quite adequately for its change in appearance as well as its retrograde motion. So with the proper choice of relative distances and periods, all the planets can be pictured as circling the sun which in turn carries them around the earth. This model, it might be pointed out, is quite different from the old Ptolemaic system of epicycles and deferents.

Here the students are baffled. They are confronted with a scheme which apparently is consistent with all the positional observations and yet it is contradictory to what they were formerly taught and have firmly accepted. A few timidly wonder if they had it wrong all the time! But the instructor warns that they do not yet have sufficient evidence to transfer the model from the status of a hypothesis to that of an accepted theory. Other observations must be sought. Furthermore the whole scheme must square with what we know about the behavior of bodies and how they influence each other, i.e., dynamics. Here gravitation is assumed as an experimental fact, and is proposed as the force which keeps these bodies from moving off into space on tangent straight lines. It is also explained (by using a demonstration) that one body never revolves about the exact center of another. Rather they both revolve about their common center of mass. On this basis, and without the use of equations, the provisional scheme of the earth being the center can be shown to be contrary to simple laws of dynamics. That is, if the planets are to

follow paths centered close to the sun, the earth must exert little influence upon them and hence be much less massive than the sun. If that is so, the center of the earth-sun system must also be close to the sun, which requires the earth to revolve around a point close to the center of the sun instead.

This contradiction requires substantial revision of the initial hypothesis, although the parts describing the rotation of the earth and revolution of the moon are unaffected. It becomes necessary to find a different explanation for retrograde motion of the planets and the result is the familiar heliocentric system. Finally there are two critical deductive tests, aberration and stellar parallax, both due to motion of the earth in its orbit around the sun. These last effects have been observed but are extremely minute, of the order of a few seconds of arc or less, and historically were not influential in the acceptance of the heliocentric system.

After spending three or more weeks wrestling with various phases of the problem as sketched above, the students are then asked to read something of its history. Although this review is sketchy, there is opportunity to discuss Aristarchus' insight, why his ideas failed to be accepted, Copernicus revival of the heliocentric approach, Tycho Brahe and why he rejected Copernicus's new scheme, and Galileo's and Kepler's important contributions which culminated in Newton's mathematical synthesis. The prediction and discovery of Neptune and Pluto serve both to give additional confirmation of the heliocentric theory, and to show how some discoveries are made in science. Students have indicated in various ways that such a historical summary, after they have grappled with the problem themselves, is both interesting and valuable.

Good sources for student reading in this problem have been difficult to locate, so the amount of material in the student manual has been gradually expanded. Particularly helpful are several specially drawn charts and diagrams. The most useful text, besides those for historical references, has been J. B. Sidgwick and W. K. Green, *The Heavens Above,* Oxford University Press, New York (1950). Globes, a coelosphere, celestial sphere, models of planetary motions from both geocentric and heliocentric viewpoints and other devices for classroom use have aided the students greatly in their three-dimensional visualization of the celestial motions.

Evaluation of Student Achievement

Formulating suitable questions for tests and examinations, whether of the objective or free-response type, is the greatest headache of teaching a course which asks a good deal more of the students than remembering a body of organized knowledge. In a very real sense, the students recognize as the *empirical* objectives of a course, those mental tasks they are called upon to perform for grading purposes. The problem approach is used in the hope that students will gain a better understanding of what scientific thinking is like and how scientific problems can be or have been solved. The memory of what some of the steps were, in a problem discussed in the course, is of some value, but the ability to recognize such steps in an unfamiliar situation is a surer test that the course has been a living experience for the student.

Accordingly, test questions are used which ask the students, for example, to decide whether given statements are fact, opinion or hypothesis; or whether a fact supports one, the other, both, or neither of two competing hypotheses. In reference to historical material, questions depend less upon accurate memory of dates and events and more upon placing significant events in proper sequential relationship. Sometimes it is possible to present excerpts from a popular article on a scientific problem and test for recognition and understanding of important steps in the attack on the problem, and how they are related.

Between 30 and 40 per cent of testing time is devoted to free-response questions, requiring either brief statements or longer expositions. Here again, one of the objectives of the course is that the students be able not only to think in critical and logical fashion, but to express these thoughts orally and in writing. This objective is further supported by asking each student to write one or more papers during the semester which are analytical in character rather than descriptive or expository.

The degree to which scientific knowledge should be tested for directly has been a perplexing problem. Students have been told that facts are not ends in themselves but means to the greater ends of understanding how scientific problems are solved. In the early years of this course it was felt that the testing emphasis should be directed almost entirely to the primary objectives of the course. Knowledge of needed facts and principles brought its own reward, because problem or "thought" questions could not be answered correctly without sufficient knowledge. But the students felt not only that the exams were tough, but that it did no good to study for them.

To meet this criticism, there has been, in recent years, an increase in the percentage of recall questions in the tests. More students are conceding that a study of content, not miscellaneous facts but relationships and concepts, is valuable. Instead of asking students directly to apply their knowledge to an unfamiliar situation, they are asked first to display their knowledge and then to apply it if they can.

There has been another means of evaluation of a more general character since the core curriculum was put into effect. Toward the end of the sophomore year, all students have been given a "Sophomore General Examination" as a measure, beyond course grades, of their progress in general education. Some of the objective tests in this examination have been the same as those given at entrance. One of those was the Cooperative Test in General Culture. This test stressed factual knowledge to a higher degree than in the freshman and sophomore core courses, but it was used for lack of anything better. Inspection of the science section of this test showed that about 75 per cent of the items were factual recall over wide areas of science. It was not expected, therefore, that the sophomores would show much improvement over their performance at entrance, if the science courses they took were restricted in coverage and de-emphasized such recall. The results of using this test for four years is most simply summarized as follows. The entrance scores were converted to percentiles on the basis of the national norm for *sophomores*. The average percentile for these entering groups was 46. Upon the same norm the average percentile at the end of the sophomore year was 76. There is no doubt that other science courses taken by the students contributed to this gain, but this could hardly account for all of it. It can hence be concluded that the students do add to their science knowledge from courses which do not stress the memory of this knowledge.

In recent years the Cooperative General Culture Test has been replaced by several tests developed by the Cooperative Study of Evaluation in General Education, of the American Council on Education.[7] The test used in science is called, "A Test of Science Reasoning and Understanding—Natural Sciences, Form C."[8] It contains 50 items which are based upon four or five passages which the students first must read. The general knowledge assumed is that which a college freshman would be expected to have at entrance. The questions ask students, for example, to recognize whether statements quoted from a passage are statements

[7] Paul L. Dressel and Lewis B. Mayhew, Editors, *General Education: Explorations in Evaluation*, American Council on Education, Washington, D. C. (1954).

[8] This form and Form D, in Natural Science, and two similar tests, one in Physical Sciences and one in Biological Sciences, are all available from Educational Testing Service, Princeton, New Jersey.

of a problem, a hypothesis, a test of a hypothesis, a conclusion, etc. Other questions ask them to recognize valid procedures for finding scientific answers to problems. In general, this test is in much closer harmony with the objectives of many of the newer types of general education courses in science. Colgate University was one of some 16 colleges and universities which were represented on the committee which developed these tests.

Experience in the use of this test of science reasoning is summarized in the table below. There was no opportunity to provide any other comparative data on these groups, such as scholastic aptitude. Hence the interpretations of the gains, especially for the small groups, is difficult. It should be noted in passing that for these two college classes, wider privileges than at present were granted for substituting other science or mathematics courses in place of Core 1 or Core 2, if they were enrolled in the A.F.R.O.T.C. Program. Hence a comparison group without either of the science cores is available.

EXPERIENCE WITH A.C.E. TEST OF NATURAL SCIENCE REASONING AND UNDERSTANDING, FORM C AT COLGATE UNIVERSITY

Group taking:	Class of 1956 No.	Class of 1956 Mean Scores At Entrance	Class of 1956 Mean Scores Sophomore Gen. Exam	Class of 1956 Gain	Class of 1957 No.	Class of 1957 Mean Scores At Entrance	Class of 1957 Mean Scores Sophomore Gen. Exam	Class of 1957 Gain
Core 1, not Core 2	23	25.26	34.52	9.26	17	27.11	35.41	8.30
Core 2, not Core 1	28	26.57	35.57	9.00	21	26.04	32.61	6.57
Both Core 1 and Core 2	130	27.18	35.71	8.53	204	27.69	36.26	8.57
Neither Core 1 nor Core 2	51	27.50	34.17	6.67	38	26.68	32.84	6.16
Total	232	26.94	35.24	8.30	280	27.39	35.47	8.08
Selected section of high general ability					18	30.94	41.44	10.50

It seems clear that the maturing process of 20 months in college enables a student to make a higher grade when he repeats a test of this kind. His vocabulary is larger and he has learned to read more carefully and perhaps more critically. But the science core courses, even when taken a year before the retake, seem also to make an additional contribution to whatever abilities this test measures. It is also gratifying to note that the average gains shown in the table are substantially greater than the average gain for 790 students in six colleges of the Cooperative Study, which was 3.37 points on a similar Form A of the test.[9] Finally, the table shows that when one section of Core 1 is composed of students selected from the top 10 per cent of the class in overall ability, and taught by an instructor who is in sympathy with the objectives of the course, the gain can be larger than for any other group. This experience has been the same when the test in Science Reasoning and Understanding—Physical Sciences, has been used as a pretest for Core 1 and incorporated in the final examination as a posttest.

Perhaps the ideal evaluation of the course described in this paper would be some measure of how a person's attitude and way of thinking have been altered ten years later. But even if such an evaluation could be accomplished there is serious doubt that much would be discovered. One fifth of a person's intellectual experience for a few months, even if vivid and arresting, is unlikely to survive in recognizable form after dilution by an additional nine years. However, the more subjective means of judging, by questionnaires and unsolicited testimony, indicate that many students have developed new comprehension of critical

[9] Footnote 5, p. 128.

thinking in science and have been surprised to find how generally successful in explaining the facts many "wrong" hypotheses are. They have also developed greater respect for earlier scientific efforts.

AREAS OF DISSATISFACTION

Anyone who has worked with a general education science course for ten years and has read of or visited others, is bound to have objectives and desires which go far beyond the limitations of time and facilities within which he is working. If both of the science courses, physical and biological, were expanded to one year each, the present staffs would find many uses for the additional time. They would add some problems and spend more time on certain of the present ones, allowing wider sampling of science areas. Students have sometimes complained that the present problems lie too much in the realm of theory. Some of the added problems could be more closely related to practical affairs. At present, some small attention is paid to reading and analyzing current popular articles in science. This would probably be expanded.

Little mention has been made of laboratory work, for no regular laboratory meetings are scheduled. Some observational projects are now performed in the problem on the solar system, and others are being added. Once, during the problem on the atmosphere, the students attend a demonstration laboratory containing several set-ups related to liquids and gases which they must study and analyze. If, in the future, more time and additional space were to become available, laboratory would doubtless be introduced as much as feasible in the present problems and added problems would be chosen with their laboratory possibilities in mind. There is no question that the laboratory, when properly used, is an effective way to confront the student with a small portion of the real world. If its use is carefully planned the complaint against cookbook instructions carried out in a perfunctory manner can be successfully met.[10]

Whether any change will occur in the time allotment for these science courses is unpredictable at present. If it should take place, it is quite unlikely that non-specialists in science would be required to take more than one of them. Just as the problems now used are only samples of much larger areas of scientific knowledge, so are all required general education courses only samples of the total realm of knowledge and thought that we should like students to explore. Although anything approaching complete coverage is a chimera, it must not be assumed that these general education courses provide students with their last opportunity in the area. If properly taught, they will open new vistas which the students can follow for the rest of their lives.

[10] C. L. Henshaw, "Laboratory Teaching in General Education Courses," *Am. J. Physics* 22, 68–75 (1954).

THE ORGANIZATION, INSTALLATION, IMPLEMENTATION, AND ADMINISTRATION OF A COURSE IN PHYSICAL SCIENCE DESIGNED FOR GENERAL EDUCATION *

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I. THE PURPOSE OF THE STUDY

THIS project relates some of the experiences and problems encountered in developing a course in physical science designed for general education at the college level, and presents some of the materials used in the organization, installation, implementation, and administration of the course. It relates some of the experiences and materials used in (a) Experimental and (b) Controlled Groups in physical science courses and describes how a faculty, student body, and administrative officers worked cooperatively on the problems of general education science.

Three specific questions had to be answered. They are:

1. What are the types of situations, problems, and interests most likely to challenge the individual in the course of his living in a democratic society, and how are these related to our institutions and ways of living?
2. What kinds of abilities and traits do we seek to develop in our students as we help them prepare for effective participation in our society?
3. What problems, abilities, etc. in Numbers 1 and 2 could be incorporated in our psysical science course designed for general education?

II. PHILOSOPHY OF THE STUDY

Many fine investigations have been carried on having for their purpose the determination of the content for a course in general education science [1] [1, 2]. These studies have been largely from the teacher's and administrator's point of view, rather than that of the pupil's [3]. Many of these studies have been concentrated on analyses of textbook or course of study content. In doing so, it seems, the fundamental problem of what the pupil thinks has been overlooked. Studies of the basic needs of pupils in approaching the study of science, and the adjustment of content to the varying interests of different levels of maturity, seem to be more basic than statistical studies concerned with the agreement or disagreement of content in the current textbooks or courses of study [4].

General education, as conceived at Morgan State College, is that body of experience the college feels obligated to provide for all students which will enable them to effect a satisfactory adjustment to the ordinary exigencies of life which all citizens must face. This institution believes, further, that this central objective cannot be achieved through courses and classroom controls alone, but that a broad association with all of the academic, cultural, aesthetic resources of the college community is indispensable. Above all, a Morgan College student must be granted every opportunity to share in the many facets of campus life. Whenever possible, the college must also exert its influence in aiding its students to intellectualize their many experiences in the wider community of the City, the State, the Nation, and the World.

The general objectives of the general education program at Morgan State College are:

A. To provide opportunity and experience in the major departments of human knowledge
   1. Humanities
   2. Social Sciences
   3. Natural Sciences
   4. Communications

B. To provide experiences in healthful living

* Based on a project submitted to the Advanced School of Education, Teachers College, Columbia University, in partial fulfillment of the requirements for the degree of Doctor of Education, 1953. Paper presented at the Twenty-seventh Annual Meeting of the National Association for Research in Science Teaching, Hotel Sherman, Chicago, Illinois, March 30, 1954.

[1] It is not possible to include here the comprehensive review of the literature to be found in the original study. References (1) and (2) are representative.

C. To develop an understanding of social dynamics and human relations
D. To expand the concept of world mindedness
E. To evolve a philosophy of living consistent with democratic ideas and demonstrated through action
F. To develop a sense of values revealed through character.

General education at Morgan State College may be thought of in still another sense, namely, that it is seeking an integrated type of educational experience. Such integration is being sought through two chief means—curricular designs that emphasize the integration of materials around a few dominant ideas or problems, and teaching methods that provoke a student to relate continuously the different materials he is considering.

III. PROCEDURES FOLLOWED

A General Education Science Committee was appointed by the administration to study the problems pertaining to the organization and implementation of general education science courses. This committee consisted of faculty members from the Departments of Biology, Chemistry, Physics, and Science Education. The Chairman of the Department of Science Education was elected chairman of the General Education Science Committee.

The Committee divided itself into two sub-groups:

1. Those teaching the physical science survey courses, or chiefly concerned with the physical sciences.
2. Those teaching the biological sciences or biological science survey courses.

During the first few meetings of the subcommittees, much time was spent studying the recommendations of the *General Education Committee,* studying what had been done in the physical science survey courses, and organizing the work so that each member of the committee could contribute something toward the goal. The chairman realized that full cooperation and participation were necessary for success and that some members of the committee had to be *sold* "Science for General Education."

The committee proceeded cautiously, realizing that *change in and of itself does not assure improvement.* It was important to maintain a sense of continuity and of stability while making changes to meet the needs of students and the needs of society. These factors, however, should not be taken by teachers as an excuse for doing nothing as this would only lead to an increasingly ineffective school program. The real problem then was not whether there should be change, but by what possible means could the most desirable results be achieved.

Some of the criteria that were used by the Subcommittee that might be used in any locality as a basis for the evaluation of demands for the ideal change in the curriculum are:

1. Does this proposed change lead from where we are to where we desire to be by the most effective means?
2. Is the proposed change consistent with democratic values?
3. Is the proposed change a reasonable area of activity for our school?
4. Does the proposed change have or will it likely have the support of the administration and community?
5. Does the proposed change relate to the lives of the students so that more meaningful and useful experiences will be obtained?
6. Would the change displace other curriculum areas of greater value to the students?
7. Is there need for a structural change or merely a change in emphasis on some phase of the program?

The committee studying the physical science program realized that an awakening among teachers of general education science in liberal arts colleges is long overdue. Bingham and West [5] reported these findings in 1948:

> The movement to provide an adequate orientation in science for all college students is gaining momentum, especially in teachers colleges and certain private ones. There is need for much improvement in this regard, however, especially in the junior colleges, the Negro colleges, and large universities.

Fraser [6] recommended that the general education curriculum at Morgan State College be redesigned to provide a unified and broad background for *all* students. He stated that students should take two well-integrated courses in the biological and

physical sciences of six semester hours each as part of their program of general education.†

The previous course in physical science, designated as Science 102, Physical Science Survey, was limited to three semester hours and was required of all non-science majors. Designed chiefly for freshman students, it was taken either the first or second semester of their first year at Morgan State College.

The large number of freshmen not majoring in chemistry, biology, or home economics made it necessary to have from six to eight sections of Science 102 each semester with approximately 35 students in each section. The teaching staff consisted of members from the Departments of Chemistry and Physics.

The methods of instruction consisted chiefly of formal lectures with an occasional demonstration and covered subject-matter areas of astronomy, geology, meteorology, physics, and chemistry. Emphasis was placed on memorization of facts, and much specialized subject-matter was introduced in the course—especially in the area of specialization in which the teacher was most competent.

The committee recognized these problems and proceeded to study ways and means of organizing and implementing a course that would better satisfy the needs and interests of students. Much experimentation and study were necessary and improvements were slow.

In order to determine what could be done to improve our courses in general education science, the committee developed questionnaires, conducted interviews with students and faculty members, and sought improved techniques of classroom instruction by examination of recent literature pertaining to the subject. From these studies, an Experimental Course in Physical Science was developed.

† The program of general education at Morgan State College required that the student complete thirty semester hours in courses as follows: English, 12 hours; history, 6 hours; biological and physical science surveys, 6 hours; and health and physical education, 6 hours. Students majoring in biology, chemistry, or home economics were excused from science survey courses.

THE EXPERIMENTAL COURSE IN PHYSICAL SCIENCE

The purpose of the experimental course was to determine which of two different types of courses was better for accomplishing the objectives of general education physical science at Morgan State College. The two courses involved were:

1. *The Physical Science Survey Course* (the traditional physical science survey course of three semester hours).
2. *The Problem Area Course* (the experimental course of three semester hours using the "block-and-gap" approach).

Students enrolled in both courses during the 1950–51 session were young men and women seventeen to twenty-two years of age. The proportion of men to women in each group was approximately 40 per cent. Five sections were involved in this study, and the class sizes were as follows:

Section "A"—32 pupils—The Physical Science Survey
Section "B"—28 pupils—The Physical Science Survey
Section "C"—30 pupils—The Physical Science Survey
Section "D"—26 pupils—The Problem Area Course
Section "E"—34 pupils—The Problem Area Course

All five of these sections were taught by the author. In addition to these, there were three other sections that were taught the traditional survey course in physical science. Students enrolled in the various sections were not informed that Sections "D" and "E" would be an experimental course in physical science. The majority of the students in the eight sections were freshmen, preparing to teach non-science subjects in secondary schools or pursuing the liberal arts curriculum for other purposes. Most of the students had completed the traditional general science and biology courses in their high school work, but very few had courses in chemistry or physics at this level. Approximately 70 per cent were residents of Maryland, with the neighbor-

ing states contributing most of the remaining number.

The college program at this level was quite rigid, and most students took the same subjects, such as English Composition, History, Health, Physical Education, etc. Therefore, the learning experiences in other subjects were approximately the same for the groups used in this study.

The plan that was followed in this study consisted of three main steps: (1) the administration of the initial tests, (2) the application of the experimental and control teaching procedures, (3) the administration of final tests. Subordinate to these main steps was the equating of the pupils on the basis of two measures of learning potential, namely, the intelligence quotient and the initial test score.

Close correlations existed between those in the experimental and control groups at the beginning of the semester. All five sections involved in this study were kept as nearly equal as possible in class size, number of class periods, illustrative materials, references, and individual conferences with the instructor. The chief difference was the method of presentation and the nature of the content of each course.

The controlled groups were given the traditional physical science survey course. This course was conducted on a time scheduled basis as follows:

Unit in Astronomy	3 weeks
Unit in Meteorology and Geology	3 "
Unit in Chemistry	6 "
Unit in Physics	7 "

The initial semester's work in physical science contained descriptive astronomy, meteorology, geology, chemistry, and physics. An effort was made to integrate these units by describing the universe without using advanced mathematics, by showing the interrelationships of matter and energy, etc. The lecture-demonstration method was used most of the time in order to cover course content within the time limits set in the above schedule.

The content for the Experimental Groups was not divided in accordance with any set schedule or time limit for each "block" of work. The blocks were determined by teacher-pupil planning.

The experimental course was chiefly a "Problem Area Course"; based on those problems students and faculty thought were most significant. The problems of the experimental course were not studied in a prescribed order and there was no time limit set for each problem. Subject matter was used as a tool for understandings rather than an end. Some of the problems considered in the experimental course are as follows:

1. What is man's present conception of the universe?
2. What is the interior of the earth like?
3. How does science help our government enforce pure food and drug legislation?
4. How does physical science help my community prevent and extinguish fires?
5. How can a knowledge of physical science qualify me to support intelligently the necessary public services?
6. How can physical science help me to choose suitable structural materials for my home?
7. How can physical science help me to choose effective and safe antiseptics, dentifrices, cosmetics, etc.?
8. How can I heat my home economically, preserve foods, select and care for clothing?
9. How can physical science help our country to replace scarce essential materials needed for peacetime or national defense uses?

Near the end of the first semester, a battery of tests were given to both the experimental and controlled groups. The results were as follows:

Experimental Group

Test	Class Average
Cooperative General Achievement Test, Part II	.7912
Fact, Theory, Misconception Test	.8245

Of the 82 pupils remaining in the physical science survey course (the Controlled Groups) the results were as follows:

Test	Class Average
Cooperative General Achievement Test, Part II	.6646
Fact, Theory, Misconception Test	.6730

This investigator thought these results were significant and asked that the two tests be administered to the noncontrolled groups,

Sections F, G, and H, which were taught the physical science survey course by other instructors. The results for these sections averaged .6502 and .6677 respectively.

At the end of the second semester, using a new experimental group and a new controlled group, there was a greater difference in the averages—and in favor of the Experimental Groups. If our evaluative instruments were valid and reliable (and we believe they were), then the Experimental Course based on significant problems was a better course than the physical science survey course as taught at Morgan State College.

A second year of experimentation with experimental and controlled groups was conducted to improve the new course and remove some of the obstacles found in its administration. Then a syllabus was developed for the new course which was offered to all sections beginning with the school year 1952–53.

The syllabus is the outgrowth of two years of intensive effort on the part of the staff to develop a course that will satisfy the general objectives as outlined in the program of general education science. During this period, mimeographed lectures, outlines, and demonstrations were prepared for use in the course. Numerous aids were employed. This material has been further revised and organized to form the basis of of the present syllabus in use. The syllabus outlines the possible subject matter, cites "indispensable" readings (as well as optional readings), and occasionally supplements the "blocks" with summaries, passages, etc. No definite effort has been made to classify the course as to type, content, or approach. We do not believe that it would fit comfortably into any one category. The students at Morgan State College require a "comprehensive" course as well as a "practical" one, in which they learn many skills that are useful in everyday living. The content is flexible and emphasis varies with national and international events. For convenience, we may classify the course into two areas:

1. Those areas of physical science that the college community agrees that "every Morgan student should have."
2. That area, or areas, of physical science that the individual student wants for his own satisfaction regardless of what his classmates are interested in.

The first area is the area that we can talk about and have already described to some extent; the second area is the difficult one to discuss in detail. We simply call it "the individual activity" which is required of all students taking physical science. It may consist of doing one or more projects, reading books that the student is interested in, preparing a science notebook, or making something in the laboratory. The scope is so wide that its many activities have satisfied practically all of the students taking the course. Students have reported that it is the most interesting part of the course.

The more versatile members of the staff are able to set up situations within which his special-interest students will identify challenging problems. It may be argued that this is a proper procedure when the purpose is to educate for a career in some specialized area. Our reply is that we are to provide guidance for the student and to encourage and develop talent wherever it is found. Our chief purpose, however, is to set up situations within which the students may identify and deal with their personal problems. In this case, selections of learnings to be sought and of materials to be used in the learning process are made with reference to the present interests and needs of the students. These will be discovered in the activities necessary to maintaining one's place in the community and in the social organization. They include use of resources; advancement of industry; maintenance of personal and public health; adjustment to customs, feelings, and folklore of people; and relations within the home and family, including love and courtship, growth and development of children, and maturing and aging of adults. Success

in achieving these goals is closely related to the competence and interests of the science teachers offering the course.

SUMMARY AND CONCLUSIONS

This has been the story of how one college faculty studied its curriculum in the light of its students' needs for the purpose of improving the general education program of the college. Progress has been exceedingly slow at times and often discouraging, but it is now realized by most of those engaged in this program of general education that success depends upon the close cooperation of administration, faculty members, and student body. We are still not satisfied with our course in physical science designed for general education, but we are making progress. We feel that the course is an essential part of the intellectual training and experience of the students in the general education area at Morgan State College and that it is receiving good response from them. We are encouraged with the outlook.

Paramount conclusions of the project are as follows:

1. Every community is unique in that its qualities are determined by its physical and biological features, the cultural heritage of its people, and by other variable factors. At the same time communities are similar in many ways.
2. The college should be looked upon as a regional institution deriving its objectives, or purposes, or reasons for being, from the region, or community in which it serves.
3. For most non-science majors, a different kind of course is needed from the specialized courses provided in the various science departments.
4. A single course in a single science is not enough to give an adequate perspective of the natural world to the educated mind of today.
5. The "block-and-gap" approach is better than the superficial survey or diluted orthodox science course.
6. The syllabus and outline for a course in physical science should be built around areas of living, rather than areas of subject matter.
7. Student suggestions and criticisms can be of value in locating weaknesses in a program designed for general education science.
8. The implementation of a program in science for general education is far from simple, because there is no single method of satisfying all faculty members and all instructors of the course as to the aims, objectives, methods, and materials to be used for the course.
9. Evaluation instruments and methods should consist of carefully constructed tests with both objective and essay type questions. In addition to tests, observations, interviews, projects, reports, etc. may be used. Formal and informal conferences provide the teacher with excellent opportunities for evaluation. Evaluative techniques should be employed both inside and outside of the classroom.
10. The teacher should keep accurate records of the progress of each student.
11. Committees and individual teachers of science for general education should be continuously concerned with the evaluation of subject-matter, and with the methods, procedures, and materials used in the course for the purpose of making further improvements whenever possible.

In summary, these conclusions imply that the program of general education science be flexible enough to allow the teacher to capitalize on the special interests and capacities of pupils, and to organize the work so as to encourage the individual to make his own particular contribution to group undertakings.

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"EXPLORATIONS IN THE SCIENCES"—A PRELIMINARY REPORT *

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In the fall of 1951 the Science Division of Hunter College set up a committee to investigate the feasibility of formulating a course in integrated science in a general education program for students who were majoring in areas other than science.

This is a report of the accomplishments of that committee to the present time.

The Committee on Developing an Integrated Science Program for the Non-Science Major is composed of representatives of the following departments: Biological Sciences; Chemistry; Physiology, Health and Hygiene; Geology and Geography; Physics and Astronomy; Anthropology; Mathematics; and Home Economics.

The first meetings of the committee were devoted to discussions of the philosophy and purposes of general education and the role of science education in general education programs. In the light of these discussions, the committee then examined the present introductory offerings of the various science departments at Hunter, and made a study of a statistical report on the science course selections made by a large group of non-science majors. Using a statement prepared by the chairman as a basis, the committee then proceeded to compare the practices of "traditional" education programs with those of a hypothetical program based on general education principles.

At this point, the committee decided that it was prepared to devote its efforts in the direction of formulating a science program for a phase of higher education which is non-specialized and non-vocational and is suited to serve the common needs of *all* educated men and women. For the time being, the committee is not concerned with individuals who have already elected to make their careers in scientific fields.

The committee then drew up a set of guiding principles for use in preparing the integrated science program. A draft of these principles is presented below in some detail.

At this point, the committee presented the results of its deliberations to a representative group of students. Six graduating non-science seniors were invited to a meeting of the committee. The students were previously provided with reading material on the general education point of view, with the set of committee minutes that summarized the tentative guiding principles, and with a series of questions around which a discussion could be centered. The general reactions of the students were quite favorable. They expressed some concern about the background needed for the physical sciences portion of the course. They offered some suggestions for problems that might be incorporated into the course. They saw, as the committee did, some of the practical difficulties involved in making the integrated science program a part of the curriculum.

The committee then went ahead to discuss several specific problems that might be included in the integrated science program. A list of some of the problems discussed is given below. The development of specific problems; the selection of appropriate readings; the planning of laboratory sessions and similar activities; and the selection of problems and their sequence in the two-semester course occupied most of the committee's time for approximately 70 sessions.

The committee also developed a plan of evaluation to accompany the proposed course. Some of the questions it hopes to

* Paper presented at the Twenty-Eighth Annual Meeting of the National Association for Research in Science Teaching, Teachers College, Columbia University, April 18, 1955.

answer by this means are: Have we chosen proper objectives for our course? To what extent is the course contributing towards the attainment of our objectives? Can the same objectives be attained through the use of the present introductory courses offered by the individual science departments?

"Explorations in the Sciences" has now been given twice; and is now in its third cycle at Hunter College.

The following materials will serve to give a more complete picture of the origin of the course and its present form.

1. *Objectives*

The subject matter, methods and learning materials of *Explorations in the Sciences* have been so chosen that the student should acquire, in addition to a body of scientific knowledge, certain concepts, attitudes and motivations that will contribute to his growth as an individual and as a member of a democratic society. To this end, the program aims towards developing in our students the following:

Primary

1. *An understanding of the nature of science.* Many introductory and survey courses deal largely with the *results* of scientific investigation. We hope to stress the understanding of science rather than the memorization of undigested information. This aim may be achieved by a thorough study of a few, very carefully selected, problems in science, by the case history method, by other means, or perhaps by a combination of several means.

2. *An understanding of methods used by scientists.* In this connection we should develop among other things, an understanding of how the scientist formulates his problem; how he selects certain aspects of a total situation to observe, measure and attempt to relate; how he devises his standards of observation and measurements; how he devises his techniques and instruments; how he sometimes attempts to generalize from the results of many observations; how he distinguishes between different types of evidence; how he identifies and formulates hypotheses; and how he recognizes when necessary and sufficient data are available to support a conclusion. This aim can probably best be achieved through experiences in the laboratory, by classroom demonstrations, and by studying how certain outstanding scientists have formulated and attempted to solve specific problems.

3. *An active intellectual curiosity, an openness of mind, a passion for truth, a respect for evidence, and an appreciation of the necessity for free communication in science.* An attempt should be made to show how these intellectual virtues have played a fundamental role in the rapid growth of science. It is hoped that these observations will result in the application of these attitudes to the students' own intellectual activities.

4. *An awareness of the fact that the boundaries of the categorized sciences are largely artificial.* As scientists attack more and more fundamental problems, they uncover large numbers of relationships which transcend traditional subject matter boundaries. New sciences arise from these relationships between and among the older sciences as the latter's concepts and techniques are refined and extended. This creates an increasing need for specialization and its most modern development, group research, in which teams of investigators representing different areas work on a single problem from individual approaches.

Secondary

5. *An appreciation of the unity of purpose in a program of general education.* Our fundamental aim is to develop in our students the values, attitudes, knowledge and skills that will equip them to live rightly and well in a free society. We cannot achieve this aim by the teaching of science alone. We must emphasize the fact that the intellectual values so useful in science are not the only values necessary to one's full development as an individual and as a member of society. Our students must develop also an appreciation and understanding of the other large areas of human endeavor—the humanities and social studies.

6. *An active concern regarding the application of their knowledge of science and its methods in the solution of some of the problems which face the citizens of a free society.* For this purpose, our students will need to understand the relationship between our society and technology and science. Society generally sets a problem by expressing a need or a wish. Applied science or technology, applying the fruits of basic science, attempts to find a solution which most effectively satisfies the need or desire of society. The citizens of a free society, with well-developed attitudes, habits and powers of evaluation, should be concerned that science and technology be directed towards constructive ends.

7. *An ability to view science in relation to its own past and to general human history.* This, together with the presentation of the humanities and social studies, should result in developing in our students a more complete picture of the origins, current status and trends of our civilization. We can contribute to the realization of this aim by including in the integrated science course some consideration of how the cultural, social and philosophical climates have influenced and been influenced by the scientific endeavors of man in various stages of his history.

8. *An effective power of communication in science.* The integrated course can contribute to this general aim of the curriculum by helping our students attain a degree of scientific literacy; by emphasizing the importance to the growth of science of precision in the description of phenomena and in other ways.

9. *An appreciation of the pleasure that can come from an understanding of the beauties and forces of nature.*

2. *List of Problems Discussed by the Committee*

Physical Science

1. With what kinds of phenomena is the physicist largely concerned? How does he approach the problem of acquiring in understanding of physical phenomena?
2. What is the age of the earth?
3. What are the sources of steel?
4. What is the chemist's view of matter?
5. What is the chemical nature of the organic world?
6. How are minerals identified?
7. How do we know the shape, size, density and motions of the earth?
8. How can the charge on an electron be measured?
9. How has the study of motion contributed to man's understanding and conquest of nature?
10. How does the physicist explain the interaction of matter across empty space?
11. What foundation supports the skyscrapers, bridges, and tunnels of New York City?
12. What is the nature of atomic energy and how may it be used for the welfare of mankind?
13. How is the structure of an organic compound determined?

Biological Science

1. What is the nature of a living cell?
2. How does an organism survive in a constantly changing environment?
3. What are the origins and varieties of man?
4. What is the origin of the living things we see around us today?
5. How does an individual develop from the fertilized egg?
6. Are there true races of man?
7. What is the role of water in the metabolism of organisms?
8. What is the mechanism of urine secretion?
9. Why do individuals that are biologically related resemble each other?
10. What phenomena underlie movement in living things?
11. What is the nature of life underlying its various manifestations in form?
12. What is race?
13. How does the heart operate as a pump sensitive to body needs?
14. To what part of his environment is man sensitive?
15. In what ways have changes in the mammalian limb been of survival value in different habitats?
16. How can we account for the apparently inexhaustible supply of nitrogen needed to fulfill the nutritional requirements of plants and animals?

3. *Catalog Description of the Course*

Explorations in the Sciences

132.1. 132.2—Explorations in the Sciences I-II. Each: 6 periods (2 lec., 4 lab.); 4 credits.

A study of science and scientific methods achieved by a thorough analysis of selected problems in the physical and life sciences, with emphasis upon the interrelations among the natural sciences and their relations to other branches of knowledge. The problems will be studied through discussion, lecture, demonstration, and individual laboratory work.

Students in the A.B. curriculum who did not choose the Science Group may satisfy their science requirement by taking 132.1 and 132.2. In 132.1, the integration is developed largely around physical science problems; in 132.2, the integration is developed largely around life science problems. It is desirable that college required mathematics be taken prior to, or concurrently with 132.1.

4. *List of the Problems Currently Being Studied in the Course*

132.1

1. What foundation supports tht skyscrapers, bridges and tunnels of New York City?
2. What is the nature of matter?
   a. What is the nature of inorganic matter?
   b. What is the nature of atomic energy and how may it be used for the welfare of mankind?
   c. What is the chemical nature of the organic world?
3. How has the study of motion contributed to man's understanding and conquest of nature?

132.2

1. How can we account for the apparently inexhaustible supply of the nitrogen needed to fulfill the nutritional needs of plants and animals?
2. What phenomena underlie movement in living things?
3. How does the heart operate as an instrument sensitive to the changing needs of the body?
4. What is race?

5. *Summary of Evaluation Techniques Used*

1. Detailed instructor diary for Problem 1 of 132.2.
2. Student scores on examinations administered before and after studying Problems 1 and 2 in 132.2.

3. Responses of several students in 132.2 to a pair of questions administered about a month apart, and dealing with methods of obtaining an answer to a problem in science.

4. Responses of several students in 132.2 to the question, "Can you support the sequence in which we studied the various problems in 'Explorations in the Sciences', i.e., starting with geology, chemistry and physics and going on to problems concerning living things?"

5. Compilation of the responses to the following question given as part of the final examination in 132.2, "We have not given to you, in any formal way, a statement of the specific aims of this course (132.2). Now that you have completed the course, can you state what you believe the purposes of this course to be. Please give your answer in the form of a series of statements."

6. Students' appraisal of 132.1 and 132.2.

7. Appraisal of 132.1 and 132.2 by three instructors.

6. *Some Results of the Evaluation*

It is too early to summarize the results of our various evaluation techniques. Several results are, however, obvious.

1. All of the students who have taken *Explorations in the Sciences* have stated that the course was extremely worthwhile intellectually, and that their experience was a very enjoyable one.

2. The instructors who have given the course have worked extremely hard. Their specific comments regarding the course closely paralleled those of the students.

3. The results obtained in the pre- and post-test techniques and in parts of the final examinations indicate that most of the students acquired a high degree of subject matter competence.

4. The responses to the two questions on how to obtain an answer to a problem in science indicated that most of the students had acquired a degree of sophistication in this area, too.

5. The *students'* formulation of the aims of the course given in response to a final examination question, were highly gratifying to the instructors.

6. One or two of the students experienced some difficulty because the course readings consisted of reprints of original articles, translations of early scientific writings and similar material rather than of traditional textbook assignments.

7. Each semester of the course is now taught by a single instructor. Our committee is considering the possibility of having a specialist for each separate problem.

THE DEVELOPMENT OF A GENERAL EDUCATION COLLEGE CHEMISTRY COURSE *

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Background for the Study

IN early history the teaching of science was initiated in harmony with the goals then established. Present first-year college chemistry teaching is remiss in keeping pace with the times. The President's Commission on Financing Higher Education in its report, "Nature and Needs of Higher Education," (1952—p. 17), says "Liberal learning has suffered from the growth of knowledge through specialization, until many an educator has surrendered the concept of man as an educated being to the concept as a specialized expert."

There can be no doubt that we are living in "the scientific age." We might say that we are well into "the atomic age." Progress toward meeting contemporary needs has not been commensurate with the increased importance of general chemistry for all. B. Lamar Johnson in "General Education in Action," a Report of the California Study of General Education in the Junior College (pp. 200–201) says: "Despite the potential value of science for *all* students, these courses are typically taught with major emphasis on materials useful to the few students who will continue in advanced work in the field of science." Current teaching emphasizes the training for specialists and little emphasis is placed upon the needs

* Based on dissertation in Partial Fulfillment of Requirements for the degree of Doctor of Education, University of Florida, 1955. Presented at the Twenty-Eighth Annual Meeting of the National Association for Research in Science Teaching, Teachers College, Columbia University, April 18, 1955.

of the majority. In the words of the President's Commission referred to above, "Today's college graduate may have gained technical or professional training in one field of work or another, but is only incidentally, if at all, made ready for performing his duties as a man, a parent, and a citizen. Too often he is 'educated' in that he has acquired competence in some particular occupation, yet falls short of that human wholeness and civic conscience which the cooperative activities of citizenship require."

A need in our present dynamic society is to have the general college citizen understand about science, what it is, and how it operates. The influences of scientific and technological advances on all aspects of human endeavor have led to increased need for the maximum number of the members of our society to understand the principles and potentialities of these as they relate to daily living. A study of the situation discloses omission in satisfactory provision for the layman's interest in scientific fields. It also shows that most of our present teaching of chemistry is done by instructors who are specialists, from texts written by specialists, and is geared toward specialization. There undoubtedly is indication that present course content and methods are not in harmony with currently-accepted educational philosophy and laws of learning.

Purpose of the Study

The purpose of the study is to develop philosophically a first-year general education college chemistry course which will serve the general education student as well as the specializing student. The course is based upon modern philosophy of science and education with emphasis upon objective scientific thinking.

Assumptions in the Development of the Course

Four assumptions are made as a basis for the course, namely:

1. That in our democratic society objective thinking based upon understanding of scientific principles relating to the structure and interaction of matter leads to a better life and should, therefore, be a part of the education of all.

2. That the chief function of a general college chemistry course is to provide experience in objective thinking regarding the structure and interaction of matter, especially as it relates to life in our society and culture.

3. That one learns most effectively when new learnings are associated with past experiences in such a way that is meaningful to the individual and when he sees that they may be used for the purpose of controlling, predicting, and testing future experiences.

4. That a general education college chemistry course should begin with atomic theory and be developed upon it.

Criteria in the Development of the Course

To select and organize content and experience in keeping with these basic assumptions, criteria were established. Applying the fourth basic assumption, those materials concerning the atom which were also in agreement with the other basic assumptions were considered. The criteria are:

1. Relatedness—of each part to the basic assumption regarding the atomic theory, of each part to each other part, of each part to the importance chemistry plays in the life of the individual, and of each part to the past experience of the student.

2. Flexibility and variability—in its provision for individual differences and in its adjustability to environmental factors.

3. Continuity—in its relation to logical sequence and dependence upon past experience leading to new experience.

4. Interaction — between students, between students and instructor, and between the student and his environment, leading to active participation.

5. Motivity—in its provision for continuing interest which would lead to further study.

6. Harmony — with sound educational philosophy, with democratic processes, with modern philosophy of science, and with all that is known about the structure and behavior of matter.

7. Effectiveness—in developing objective thinking, in developing a practicable and usable philosophy of life, and in leading toward continuous improvement in man's relation to his fellow man.

Identification of Principles

To ascertain that important aspects of chemistry were not overlooked, a list of statements relating to the structure and behavior of matter was compiled from major sources. These were submitted to a jury of nine specialists in general education who are conversant with general chemistry and nine specialists who are college chemistry instructors conversant with general education. They rated them as to:

A. Their suitability for any beginning college chemistry course.

B. Their suitability only for students intending to specialize.

C. Their suitability only for the general student taking chemistry as a terminal course.

D. Their unsuitability for any beginning college chemistry course.

Fifteen ratings were received, seven from the general education group and eight from the specialist group. Three hundred and seventy-six statements were judged to be essential. The groups of the jury were nearly unanimous in their agreement. These statements were then arranged in logical sequence according to the plan of the course.

Space does not permit inclusion of the complete list of statements. The following may serve to illustrate the type used:

Chemistry is a science dealing with the structure and change of all matter.

Accurate observation and objective thinking are necessary tools in the study of chemistry.

Physical properties are distinguishing features or characteristics of matter.

The understanding of the structure and change of matter is best accomplished when correlated with its make-up in terms of atoms, molecules, ions, and smaller parts.

All matter is made up of particles (atoms, ions, molecules or combinations).

The behavior of atoms and all chemical changes in matter are explained by using the three subparticles, electrons, protons and neutrons.

Radio-active isotopes are useful as tracers in the study of life processes.

Most of the 100 elementary substances unite in various combinations to make up all matter in the universe.

There are several hundred thousand different compounds known and many new ones are made or discovered each year.

Formulas of all compounds show the number of atoms of each kind which are bonded together in the molecule or simplest combination of particles of that compound.

When molecules of a liquid are given sufficient energy, their speed becomes great enough to overcome their attractive forces. They then go into the gaseous state.

Topical Outline of the Course

- I. Introduction
  - A. Preliminary Concepts
    - 1. Meaning of Chemistry
    - 2. Chemistry in everyday living
    - 3. Observation and objective thinking
  - B. Essential Basic Concepts
    - 1. Material and methods of measurement
    - 2. The metric system
    - 3. Physical and chemical properties
    - 4. Energy and its measurement
      - a. Heat
      - b. Light
      - c. Electrical
      - d. Kinetic
      - e. Potential
      - f. X-rays
- II. Discontinuous Nature of Matter
  - A. Atomic Nature of Matter
    - 1. Kinds of matter
    - 2. Size of particles
  - B. The Atomic Theory
    - 1. Positive and negative electrical charges
    - 2. Atomic structure
      - a. Electrons and electron orbits
      - b. Protons
      - c. Neutrons
      - d. Other parts of atoms
    - 3. Atomic force
    - 4. Species of atoms
      - a. Normal atoms
      - b. Isotopes
      - c. Symbols
    - 5. Mass measurement
      - a. Atomic weights
      - b. Gram-formula units
      - c. Avogadro's number
    - 6. Atomic theory history (brief)
      - a. Early Greek theory

b. Medieval theory
c. Modern theory

III. Radio-activity and Atomic Energy
A. Alpha, Beta and Gamma Emissions
B. Nuclear Rearrangements
C. Fission and Fusion
D. Matter and Energy Relationships
E. Radio-active Isotopes
1. Natural and man-made
2. Stable and unstable isotopes
3. Half-life
4. Geiger-Mueller counter
5. Radio-active isotopes in practical use

IV. Classes of Matter
A. Elementary Substances
1. Metals
2. Non-metals and inert elements
3. Metalloids
B. Compounds
C. Mixtures
D. Heterogeneity and Homogeneity

V. Behavior of Atoms
A. Periodicity of Atoms
B. Metal Atoms
1. Atomic bonds in metals
2. Crystal structure of metals
3. Types of metals
4. Properties of metals
a. Physical
b. Chemical
c. Electron affinity
d. Activity of metals
5. Alloys
a. Types and structure
b. Properties
6. Metal ions
7. Combination of metal ions
a. Ionic bond
b. Stable electron shells
8. Oxidation and reduction
9. Electrolysis
10. Metallurgical processes
C. Non-metal Atoms
1. Types and resemblances
2. The covalent bond
3. Non-metal ions
a. Formation
b. Electron attraction in non-metal ions
4. Complex ions
5. Molecules
a. Structure
b. Constancy of numerical ratio
c. Kinds
d. Formulas
e. Equations
6. Crystal structures
7. Coordinate-covalent bonds
8. Polarity
9. Oxidation state
10. Types of reactions
D. Typical Non-metals
1. Hydrogen
2. Group IV
a. Carbon
b. Silicon
3. Group V
a. Nitrogen
b. Phosphorus
4. Group VI
a. Oxygen
b. Sulfur
5. Halogens
6. Inert gases

VI. Energy Effects on Atoms and Molecules
A. Vibration of Particles
B. Physical States of Matter
1. Kinetic energy—motion of particles
2. Solids, liquids, and gases
3. Energy and the change of state
4. Colligative properties
a. Vapor pressure
b. Osmosis
c. Boiling points—freezing points
d. Viscosity
5. Sublimation
6. Decomposition and combination
C. Pressure, volume and temperature relation of gases
1. Temperature measurements
2. Pressure measurements
3. Standard conditions
4. Molar volumes
5. Molecular weight determinations
6. Van der Waal's forces
7. Real gas behavior
8. Ideal gas laws

VII. Carbon and Carbon Compounds
A. Carbon Atoms
B. Forms of Carbon
1. Diamond
2. Graphite
3. Lampblack
4. Bone black
C. Carbon Compounds
1. Carbides
2. Oxides of carbon
3. Hydrocarbons
a. Petroleum and coal products
b. Saturated and unsaturated hydrocarbons
c. Cyclic compounds
d. Oxidation of hydrocarbons
4. Molecular synthesis and rearrangements
a. Photosynthesis
b. Industrial preparations
5. Organic functional groups
6. Molecular isomers
7. Carbohydrates
8. Fats
9. Proteins

VIII. Water and Solutions
A. Special Properties of Water
1. Physical properties and abnormal behavior

2. Solutions
    a. Solvents
    b. Solutes
3. Water in life processes
4. Water purification

B. Reactions of Molecules and Ions in Water
1. Structure of the water molecule
2. Polar solvents
3. Non-polar solvents
4. Dissociation of some substances in water
5. Separation of ions from solution
6. Mathematical relations between ions in solution
7. Colloids

C. Acids, Bases, Salts and Equilibrium
1. Relative strength of acids
2. Control of proton concentration
3. Relative strength of bases
4. Neutralization
5. Salts
6. Polyprotic acids and polyhydroxide bases
7. Acid salts and basic salts
8. Amphoterism
9. Complex ions in water
10. Electrolysis of ionic water solutions

D. Temperature Effects on Solubility

E. Effects of Solute on Physical Properties of Solvent

F. Special Factors Effecting Change and Equilibrium
1. Types of reactants and products
2. Concentrations of reactants and products
3. Temperature change
4. Light effects
5. Catalysts

Conclusions and Suggestions for Further Study

The conclusions of the study are incorporated in the course that was developed. This course was designed to meet the criticism referred to in the background of the study.

The study brings to our attention several areas which may be worthy of further study. A few of these are:

1. Evaluation of the proposed course in practice.

2. The preparation and qualifications of college instructors in general chemistry.

3. The practice in many colleges of employing graduate students as teaching assistants whose interest may not lie in teaching.

4. Teaching loads and other responsibilities assigned to general chemistry instructors and the effect on teaching.

5. The role of the laboratory.

6. The influence of testing practices as they affect objective thinking.

If first-year college chemistry is to make greater contributions in satisfying the general education ends of all students, it would appear that the whole field should be critically investigated. Such investigation would be in harmony with the philosophy of science which science instructors should promote.

A COMPARISON OF THE BIOLOGY INTERESTS OF TENTH AND ELEVENTH GRADE PUPILS WITH A TOPICAL ANALYSIS OF HIGH SCHOOL BIOLOGY TEXTBOOKS *

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I. *Problem*

As a part of the class evaluation in Biology, an attempt was made to compare the expressed interests of pupils who had almost completed the full year of Biology offered at East High School with the topics emphasized in current textbooks in Biology. In order to find how closely the interests of these pupils ranked in comparison to the topics in the textbooks, a two-part study was carried on. First, the main topics found in Biology textbooks were surveyed. Second, the interests of pupils in these topics were determined.

* Paper presented at the Twenty-seventh Annual Meeting of the National Association for Research in Science Teaching, Sherman Hotel, March 30, 1954.

II. *Procedure*

Ten current textbooks (revised dates from 1946 to 1951) were selected at random from the texts available in the Denver Schools and the University of Denver libraries. Texts organized on a natural or systematic basis and on a life function or integrated basis were both included in the survey. Each text book was analyzed, page by page, to determine the topics included. These were studied to determine the emphasis given to each by the authors, and the frequency of occurrence in the various books.

It should be emphasized that only a general analysis was made of each textbook. No attempt was made to evaluate the effectiveness of the presentation, the accuracy of the material, or the other factors of importance in judging a textbook. With a random selection and a general survey of each text, it was felt that adequate information as to topics stressed by authors would be found.

Ninety-two topics were found to be generally stressed in the books surveyed. These were ranked in the order of emphasis given to them on an average. A questionnaire was prepared on these topics. Tenth and Eleventh grade pupils in the second semester Biology classes were asked to check this questionnaire as to their interest or lack of interest in the topics listed.

In order to reduce the load of tabulation, the questionnaires were sorted at random from the total group so that the following evenly-matched distribution was available:

Boys	60	Girls	60
Eleventh Grade	60	Tenth Grade	60
"A" pupils	30	"B" pupils	30
"C" pupils	30	"D" pupils	30

The interpretation of the results was based on the difference in percentage between the YES and NO checks. Those omitted or those marked in the UNDECIDED column could not be given any real interpretation. To determine the items in which pupils in the sample were most interested and least interested, the direction and amount of this difference was computed. The statistical procedure was based on a method developed earlier for another study of student interests.[1]

Because in any study of this type some items on the questionnaire are marked so that there is no statistical significance, the report will deal only with those topics in which pupils expressed a definite lack of interest, or a definite positive interest. It should be remembered in glancing at the graphic representation of some of these results that the bars for each category simply indicate a linear direction of interest. The longer the bar to the right, the greater the positive interest; the longer the bar to the left, the greater the negative interest. However, it can not be assumed from this type of study that a bar twice as long as another denotes twice as much interest.

Of particular interest was the analysis of the relationship of the expressed interests of each of the four pupil-mark groups, those pupils receiving an "A" in first semester Biology; those receiving a "B"; those receiving a "C"; and those receiving a "D"; to the topics emphasized in the textbooks.

The following table deals with the topics receiving such number of checks as to give a result which was statistically significant. The rank of the topic, as averaged from the textbooks surveyed, is shown in Column I. The topic is listed in Column II. The degree and direction of negative and positive interests for each of the four mark-groups is charted in Column III.

To help distinguish between the four mark-groups, on the chart, the capital "A" is used to make the bar for the "A" pupils, the capital "B" for the "B" pupils, the capital "C" for the "C" pupils, and the capital "D" for the "D" pupils. Bars extending to the right of the midline indicate a positive interest. Bars extending to the left show a negative interest.

[1] Sam S. Blanc, "A Technique for a Statistical Interpretation of an Interest Survey Questionnaire," *Journal of Educational Research*, 47: 223–27, November, 1953.

Rank in Textbooks	Topics	Degree of Interest	
1	Digestion of food in the body		AAAAAAAAAAA CCCCCCC DD
1	Mendel's principles of inheritance		AAAAAAAAAAAAAAA BBBBBBBBBBB CCCCCCCCC DDDDD
6	Problems of human inheritance		AAAAAAAAAAAAAAAA BBBBBBBBBBBBBB CCCCCCCCCCCCC DDDDDDDDDDD
6	Evidence of change through the ages		AAAAAAAAAAAAAAAAA BBBBBBBBBBBBBBBBB CCCCCCCCCCCCCC DDDDDDDDD
6	Physical factors of the environment		A BBBB CCCCCCC
9	Sense organs and senses in the body		AAAAAAAAAAAAAAA BBBBBBBBB CCCCCCCCC DD
12	Nervous system and control of the body		AAAAAAAAAAAAAAAAAAAA BBBBBBBBBB CCCCCCCCCCC DDDDDDD
12	Organisms causing disease in man		AAAAAAAAAAAAAAAAA BBBBBBBBBBBBBBBBB CCCCCCCCC DDDDDDDDDDDDDDDDD
12	Reproduction in plants and animals		AAAAAAAAAAAAAAAAAA BBBBBBBBBBBBBB CCCCCCC DDDDDD
16	Structure and function of roots in plants	BBBBBBBBB CCC DDDDDD	AAA
16	Structure and function of flowers in plants	BBB CCC DDDDDDDDDD	AAAAAAAAAAA
16	Blood and its functions in the body		AAAAAAAAAAAAA BBBBBBBB CCCCCCCCCCC DDDDDDDDDDDD
16	Ductless glands and functions in the body		AAAAAAAAAAAAA CCCCC DDD
23	Using scientific names in classification	AAAAAAAAAAA BBBBBBB CCCCCCCCCCCC DDDDDDDDDDDDDDD	
23	Skeleton and muscles in the body		AAAAAAAAAAAAAA BBBBBBBBBBBBBBBB CCCCCCCC DDDDDDD

23	Heart and circulation in the body		AAAAAAAAAAAAAAAAAAA BBBBBBBBBBB CCCCCC DDDDDDDDD
31	Detailed study of the grasshopper	BBB CCCCC DDDDDDDDDDDD	
31	Effects of alcohol and drugs on the body		AAAAAAAAAAAAA BBBBBBBBBBBBBBBBB CCCCCCCCCCCCCCCC DDDDDDDDDDDDDDDDDD
31	Body defenses against disease germs		AAAAAAAAAAAAAAAAA BBBBBBBBBBBBBBB CCCCCCCCC DDDDDDDDDDDDDDDDDD
31	Darwin's theory of the development of life		AAAAAAAAAA BBBBBBBBBBBB C
38	Protective adaptations in various animals		AAAAAAAAAAA BBBBBBBBB CCCCCCCCCC DDDDDDDDDD
38	Balance of living things in nature		AAAAAAAAAAAAAAA BBBBBBBBBBBBB CCCCC DDDDDDDDDDD
38	Adaptations found in birds		AAAAAAAA BB CCCCCC
38	Waste products and excretion in body		AAAAAA BBBBBB CC
47	Structure and adaptations of fungi	A CC DDDDDDDD	
47	Structure and adaptations of mosses	A CCCCC DDDDDD	
47	Structure and adaptations of ferns	A CC DDDDDDDDD	
53	Classification of various plants	AAAAAAA BBBBBB DDDDD	
53	Personal health and hygiene		AAAAAAAAAAAA BBBBBBB CCCCCCCCC DDDDDDDDDDD
53	Various diseases of the body		AAAAAAAAAAAAA BBBBBBBBBBBBBBBBB CCCCCCCCCCCCC DDDDDDDDDDDDDDDDDD
53	Improvement of plants through breeding	DD	AAAAA BBB
59	Structure and adaptations of worms	BBB CCCCCCCCCC DDDDDDDD	
59	Structure and adaptations of fish		AAAAAA BBBBBBBB CC

59	Structure and adaptations of amphibia		AAAAAAAAAA BBBBBBBBBBBBBB CCCCCCCCCC
59	Vaccination and tests for immunity		AAAAAAAAAAAA BBBBBBBBBBBBB CCCCCCCCC DDDDDD
59	Antibiotics and chemicals in fighting disease		AAAAAAAAAAAAAAAA BBBBBBBBBBBBBBB CCCCCCCCCC DDDDDDDD
64	Life functions of living organisms		AAAAAAAAAAAAAAAA BBBBBBBBB CCCCCCCCCC DDDDDDD
64	Structure and adaptations of echinoderms	CCC DDDDDDDDDDDDDD	BB
64	Economic importances of birds		A BBB D
64	Vaccines and serums in control of disease		AAAAAAAAAAAAAAA BBBBBBBBBBBBBBBBB CCCCCCCC DDDDDDDDD
64	Animal improvement by controlled breeding		AAAAAAAAAAAAA BBBBBBBBB CCCCC
64	Various theories of evolution		AAAAAAAAAA BBBBBBBBBB CCCCCC
71	Structure and adaptations of porifera	BB CCC DDDDDDDDDDDDDDD	
71	Structure and adaptations of fish		AAAAAAAAAAA BBBBB CCC
71	Structure and adaptations of birds		AAAAAAAAAAAAAAAA BBB CCCCC
78	Structure and adaptations of mammals		AAAAAAAAAAAAAAAA BBBBBBBBBBBBBBB CCCCCCCCCCC DDDDDDDDDDDDDDDDDDD
83	Study and dissection of the crayfish	A BBBBBBBBB CCCCCCCCCCCCCC DDDDDDDDDDD	
83	Structure and adaptations of reptiles		AAAAAAAAAAAAA BBBBBBB CCCCC
85	Organization of tissues, organs, and systems		AAAAAAAAAAA BBBBBBB CCCCCCCCCC DDDDD
88	Economic importance of fish		B CCCCC DDD
92	Economic importance of reptiles		AAAA BBB CCCCCCCC DDDDDDDDD

III. *Conclusions*

This study treated a very small sampling in one school in a large city school system. One must be cautioned not to draw too conclusive results from such a limited sampling. However, within the limits of the sampling and the method used, certain interesting indications seem to be present:

1. There was a consistent correlation between the emphasis given by textbook writers to topics found in a sampling of current Biology textbooks.
2. There was no consistent correlation between the topics emphasized by authors and the expressed interests of pupils in Biology II classes.
3. Regardless of how the data was treated, there was in most cases a high agreement between the various categories and groups of pupils, both on the Tenth and Eleventh Grade levels.
4. In most cases, the interest, or lack of interest, expressed in each topic showed a high correlation among the four mark-groups of pupils.
5. In general, "A" pupils were most inclined to express interests in topics in agreement with emphasis by authors of textbooks.
6. In general, "D" pupils were least inclined to express interests in topics in agreement with emphasis by authors of textbooks.
7. The higher the grade received in first-semester Biology, the greater the number of positive interests were checked on the questionnaires.
8. No hard and fast conclusions should be drawn from this limited study. What may be true of this isolated situation may not be true in other schools and other cities.
9. It would seem that it might be of value to extend such a study to all areas of science teaching on a nation-wide scale under the sponsorship of a national science teaching organization.

SCIENCE IN NEW YORK CITY VOCATIONAL HIGH SCHOOLS *

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At present, each of the Vocational High Schools operates as a partially autonomous unit in so far as its courses of study are concerned. Science offerings vary from school to school and include high school chemistry, physics, biology and numerous applied variations of these to over 143 trade offerings. At present, the Vocational High School Division is reorganizing its curriculum patterns. Hereafter, all schools will offer similar training for any one trade.

All students in the Vocational High Schools will take a science sequence. The courses will be closely related to occupational training. In our society, it is especially important that the technician, skilled mechanic and semi-skilled mechanic not only understand basic science concepts but be familiar with applications to his area of work. The increasing complexity of tools and processes as well as the changing character of job specifications make it imperative that mechanics be prepared to adapt themselves to changing conditions. Related Science is one of the offerings which provides mental understanding essential to intelligent work planning and execution. It also provides a base for greater adaptability to changing job requirements resulting from technological developments.

The Vocational High School Division offers either trade or technical training. Trade training is either for the skilled or semi-skilled areas. Technical training qualifies the student for work as a technician or for entrance into engineering college.

* Paper presented at the Twenty-Eighth Annual Meeting of the National Association for Research in Science Teaching, Teachers College, Columbia University, April 18, 1955.

SCIENCE PATTERNS

Trade

9th yr.—General Science
10th yr.—Basic Science (Boys' or Girls')
11th yr. } Related Science
or
12th yr. } Related Technology

Technical

9th yr.—General Science
or
Industrial Processes
10th yr.—Physics or Chemistry
11th yr. }
12th yr. } Applied Technical Science

Specific Nature of Science Offerings

1. *Basic 10th Year Applied Science (Boys)*

A study was made of a number of boys' trades. The science principles which were common to all of them formed the basis for the course. The course stresses physics concepts. A number of important chemical concepts are included. Trade and shop applications will serve to motivate and test understandings.

2. *Basic 10th Year Applied Science (Girls)*

This course has been prepared to meet needs of girls who are preparing themselves for living in a scientific world, managing a home, and preparing themselves for employment. It provides concepts basic to the study of textiles, cosmetology, medical and dental assisting. The major emphasis is on applied biology. Important concepts in physics and chemistry are also developed.

Related Science

In this course science concepts are applied to analyze or plan shop and trade problems.

The content varies from trade to trade. Curriculum time devoted to it may extend through the 11th and 12th years or require but one term in that time. At present insufficient time is given to science for the television mechanic. Not all the time is required for a dressmaker.

Related Technology—11th and 12th Years

This is an experimental approach. Science, math and trade sketching and blueprint reading are fused.

Trade problems and plans are worked on with the required subject area time indicated by the nature of the problem. Some trades will require more stress on one subject than another. In any one specific problem, there will be a definite subject time allocation.

Technical Science

Technical students have a four year science sequence. The courses vary from one technical area of training to another. Obviously, the chemical technician will require courses distinct from the needs of the electronics technician.

These students take either traditional physics or chemistry on the 10th year level. Advanced laboratory and theoretical courses are offered in the 11th and 12th years. In several different areas of training advanced courses would include such titles as, Aero design, Structural Materials, Power, Industrial Design, Metallurgy, Surveying and Radio. Prior to graduation, technical diploma candidates are required to pass a New York State Technical Comprehensive Examination.

Resource Materials

New York State has assisted with the development of many manuals. Funds have been made available for the employment of qualified personnel for this work. These manuals are for the teachers' use. There is a lack of adequate pupil texts especially in the vocational-trade areas.

Teacher Personnel

It is impossible to recruit the number of qualified individuals required. Although teachers with training in physics, chemistry or biology may teach general science and some may teach basic science effectively, engineers are required to do the most effective related science teaching.

It would be helpful if teacher training institutions provided appropriate methods

courses for the teaching of basic and related subjects. At the present time, many out-of-license teachers are employed to teach the basic and related sciences. Their partial retraining is accomplished by in-service courses and through the efforts of their chairmen and their own experiences in the vocational schools among which experiences are shop visits, talks to shop and related teachers and participation in conferences. Out-of-license teachers find the teacher resource manuals especially helpful.

It is hoped that the increasing salary schedule will ultimately result in the recruitment of necessary personnel.

The Future

For the first time, all schools will be following similar science programs. Common experiences will be distilled to obtain the best practices. The coming years should see the resolution of most desirable syllabii for each of the sciences. An attempt is being made in the design of science facilities in new buildings to include elements which will permit flexibility to meet changing demands.

Liaison is being planned with the Engineering Manpower Commission so that a closer relationship will be maintained between industry's needs for technicians and the type of training offered. The relationship of trade and technical commissions known as the Vocational Advisory Board will continue to help determine the training needs for the skilled mechanic and technician.

PROGRESS REPORT ON THE DEVELOPMENT OF THE GENERAL SCIENCE CURRICULUM PROGRAM IN THE PUBLIC SCHOOLS OF NEW YORK CITY *

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At your meetings in Atlantic City in 1950 and 1951, it was my pleasure to present to you the initial plans and premises upon which a twelve-year science program was to be developed in New York City's public schools. It is even a greater pleasure to be able to report to you now at this meeting upon the progress that has been made at the 7th, 8th, and 9th grade level and to have my colleagues who supervise the teaching of science at the other levels present their reports to you in person.

About this time a year ago, we had reached a point where the report of the General Science Committee was ready to be published and implemented. Although the report presented a *tentative* outline of a new course of study, it was decided to set it in type and print it rather than to rely on the usual mimeographed format because we wished to make it easily available to everyone concerned for discussion and comment.

The new course of study provides two units for the 7th grade:

Unit 71—Getting Acquainted with Yourself
Unit 72—Getting Acquainted with Your World

three units for the 8th grade:

Unit 81—Increasing and Improving Our Food Supply
Unit 82—Improving Our Clothing and Housing
Unit 83—Making Work Easier

and five units for the 9th grade:

Unit 91—Speedier Transportation
Unit 92—Improving Communication
Unit 93—Our Atomic World

* Paper presented at the Twenty-Eighth Annual Meeting of the National Association for Research in Science Teaching, Teachers College, Columbia University, April 18, 1955.

Unit 94—Prolonging Your Life
Unit 95—New Worlds to Conquer

The basic minimum time on a 45-minute period schedule is two periods in the 7th year, two periods in the 8th year, and five periods in the 9th year. However, we permit and encourage the teaching of all of the 7th and 8th grade units within a single school year which may be either the 7th or the 8th year (preferably the 8th year) with a time allowance of four periods per week. Under this plan, we find that pupils consider the subject a "major."

This arrangement also has the advantage of reducing the pupil-teacher ratio in the sense that both teachers and pupils have fewer personalities to deal with at a particular time. This plan reduces the number of preparations a teacher must make during a week. It also reduces the number of notebooks and tests he has to rate and the number of marks he has to record.

To achieve this plan a parallel program is made with Art, giving similar advantages to the teachers and pupils of this subject. The total time devoted to each subject remains the same over the three-year span. Teachers like this arrangement.

We feel that the second innovation of the new course has great educational significance. Here at last is a *general* science course built around the life problems of people. The traditional, Aristotelian units of scientific subject matter have been cast aside and at the same time the tiresome dickering of specialists for more emphasis on their specialty has been silenced. Note it is the obsolete compartmentalization of science not the subject matter which has been discarded. This is the culmination of fifty years of effort by leading science educators to create a course that meets the needs of general education.

In the 1930's, when the first sincere attempts were made to break down the artificial boundaries between the sciences and thus to provide a generalized science course, the technique of exploring the environment was employed. Nevertheless these educators were predisposed to glorify the environment rather than to consider the needs of the pupils. Units on Air, Water, Energy, Bacteria, Food, and Reproduction were prepared along with units on Communication and Transportation and others. Teachers soon realized that while the Communication and Transportation Units focused attention upon two important problems of living, the other units dealt with a pot pourri of phenomena related in most cases to one another by a mere coincidence. Thus in the Air Unit of our old course of study (circa 1938) we found such odd bedfellows as the theory of flight, the production of sound, the causes and prevention of fire, and the respiratory functions of leaves, mammals, and fish. Why? Because in all of the above, air is employed in one way or another.

The Air Unit described here is not an isolated instance. Similar incongruities may be found in the organization of the Air Unit in many courses of study throughout the country. In the same way, if space permitted, it would be possible to show the artificiality of the Water Unit, the Energy Unit, the Food Unit, the Bacteria Unit, and the Reproduction Unit. No one, save a scientific specialist, has any initial interest in any of these units but each contains much that is of real concern to everyone. All along the best teachers have modified the official course of study to give it vitality and significance. But the strict conformists continued to teach from the printed pages of the course of study and the textbooks based thereon. A plateau had been reached and for this group no further progress could be expected until a new official "cook book" would be issued. The idea of disturbing the status quo does not appeal to this group for obvious reasons.

Then came the atomic bomb. Suddenly, even the most vegetative among us realized that survival demands alertness to changing times; that there are no hard and fast boundaries between the sciences; and that in the whole world the problems of living

with change are the real concern of everyone, particularly educators. The general science course offers us a splendid opportunity to prepare our pupils for successful living in this kind of world.

Yet we cannot attempt to deal with every aspect of every vital problem. The best we can do is to call attention to the most universal problems; indicate the scientific approaches to the solution; and provide some resource material to guide the teacher. We must depend upon the alertness and ingenuity of our teachers and their pupils to select the implementation most appropriate to their needs and interests.

The only requirement the new course imposes upon all teachers of science is that no unit shall be omitted. Each deals with a whole sector of vital problems which no one can avoid entirely in life. But within the scope of the unit, each teacher and class may decide together the emphasis they will give to it. The development of the subproblems and related problems in the Red Hook District may be the same or quite different from their development in Harlem or Coney Island or any other district of our vast city. Still, we are confident that everywhere within New York City and beyond its boundaries people will be concerned for many years with some aspects of problems such as:

How do we learn about our surroundings?
How accurately do our senses serve us?
How can the methods of science aid our learning?
How are we affected by the air around us?
Why is the use and conservation of water of concern to all?
How do the movements of the earth affect us?
What are the sources of our food supply?
How can we increase our food supply?
How can we choose and use clothing wisely?
How are dwellings made and serviced for good health and safety?
How can available energy affect our standards of living?
How does an understanding of the form and composition of materials help us to discover new uses for them?
How are infectious diseases fought?
How do present methods of communication help people to understand each other better?
How may we make a permanent record of events as they occur?
Why is improved transportation important to us?
How can continued scientific research better our lives?
How is chemistry contributing to a better world?
What does the future of science have to offer?
How can scientific avocations make our lives more useful and enjoyable?

It should be noted that among these problems (only a sampling of the many suggested in the course) are those which have educational, vocational, and ethical guidance implications. Also note that the child will be taught to appreciate the importance of the scientific methods of discovery. He will be shown how to direct his leisure time activities and thoughts to creative and productive scientific hobbies.

At present the task of implementing this course is being carried on in twelve pilot schools of different types in various parts of the city. These schools and others are kept informed of the progress being made through mimeographed bulletins, staff conferences, and inservice courses. Cooperative assistance is being given by other bureaus, departments, and agencies. The entire program is under the supervision of the Bureau of Curriculum Research. The plan calls for completion of the implementation of the 7th grade units by June 1956, the 8th grade by June 1957, and the 9th grade by June 1958. Progress is being made according to schedule and if it continues as well, the new course will be introduced into all New York City public schools by September 1958.

SUMMARY OF REMARKS TO NARST MEETING IN NEW YORK CITY ON APRIL 18, 1955

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THE chemistry syllabus in New York City up to about 1940 showed little change over the earlier syllabi which had been introduced as far back as 1910. The emphasis was largely on college preparation and the course was predominantly descriptive in nature. Laboratory work consisted largely in a series of experiments done in rote manner, the results of which the student was aware of in advance of the experiment.

Due to the impetus of the Second World War the syllabus became "war conditioned" and units were removed in place of those that contributed to a greater understanding of the chemistry of modern warfare. Emphasis on fighting fire bombs, composition of explosives and the chemistry of war gases were some of the topics that were featured.

The nature of the pupil population began to change sharply at this point. The importance of preparation for college decreased somewhat in favor of a more functional approach to the subject. As a result a syllabus in functional chemistry called "applied chemistry" was developed. The general level of the so-called academic student also dropped considerably at this point so that the classical or college preparatory course became diluted. This dilution tended to reduce the course to one covering minimum essentials. Due to practices in feeding schools called "continuous progress" or "100 per cent promotion" the general level in the high schools continued to drop.

With the advent of the Korean War and the growing emphasis on technology a committee was set up to survey the entire science situation in New York State. Committees for syllabus revision were nominated. There is at present a syllabus in chemistry which is an outgrowth of the work of this committee and is being tried experimentally in a few schools. The new syllabus recognizes the advances in science and technology and has given them a prominent place in the organization of the course. The syllabus also de-emphasizes the minutiae of previous syllabi and stresses the "big ideas" such as the periodic table and the atomic theory.

The educational pendulum is now beginning to swing away from the needs of the slow learners and is beginning to recognize the problems of the rapid learner. Under the influence of the School and College Study, college level courses for superior high school seniors are now being offered in many secondary schools. Such courses provide an outlet for a more logical kind of acceleration but more important, is the fact that opportunities are provided for the rapid learners to work up to capacity during their supposedly least productive school year, the senior year.

There are still a number of unanswered questions that should be considered in evaluating any syllabus in chemistry:

1. How can the laboratory period best be utilized? This question involves not only the matter of time but the content of the experiment as well.
2. What methods of selection should be utilized to determine which students take the applied course and which will take the college preparatory course?
3. There has been a tremendous change in freshman college chemistry. To what extent shall the secondary schools be required to recognize these changes? The whole problem of integration between high school and college chemistry needs to be considered.

SCIENCE IN THE 19TH CENTURY NORMAL SCHOOL *

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All too often there rings forth on the elementary school battlefront, an ominous cry that the teacher is woefully unprepared to teach simple science. To this is appended an earnest warning that the rapid growth of modern technology and science calls for unprecedented efforts to develop maximum scientific literacy. The alternative to such action is certain doom. One facile proposal which will enable our society to "escape" disaster is an increase in the number of science hours imposed on the teachers college student. This approach is a favorite with college science departments which further guarantee success by emphasis on the techniques of scientific thinking. No one, obviously, can learn all the facts and principles of science which he "should" know. He can, however, learn *how* to find the answers to his questions and to the questions which children will ask him, and by so doing, achieve a measure of scientific competency. By stressing the methods of science, science teachers will be able to overcome the difficulties presented by lack of time for a thorough study of the sciences.

These remedies which are thus summarized so briefly have merely been renovated, not newly invented. They were thoroughly tested by the 19th century normal school which was also forced to grapple with the problem of generating student *savoir-faire* in science. Despite many superficial differences, there is this particular link in outlook and endeavor between normal school and teachers college science, and the author has attempted to describe the normal approach to its science problems in the belief that the historical experience set forth may profitably be utilized today.

To fulfill this aim, the writer, drawing upon extensive research, sought to answer four major questions: *First,* how much science was required in the normal schools? *Second,* what were they striving to accomplish by these science requirements? *Third,* how did they manipulate the facts and principles of science to attain their goals? *Fourth,* were they successful in what they tried to do?

The Theory of the Massive Dose

For many years, compulsory science courses consumed from 20 to 40 per cent of all class time in the conventional curricula of the 19th century. The normal schools sought to realize their goals by means of a massive dose of science. Indeed, had they increased science time allotments any further after the middle sixties, they would have been closer in spirit to such scientific schools as Sheffield and Lawrence than to teacher-preparing institutions.

Even prior to the sixties, years during which few students remained for more than a term or two, the sciences were accorded a place of honor in the curriculum. As early as 1839, Mr. Peirce, the principal of the first state normal school at Lexington

* Based on a dissertation "Science in Selected Normal Schools of the 19th Century," accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, Yale University, 1954. Paper presented at the Twenty-Eighth Annual Meeting of the National Association for Research in Science Teaching, Teachers College, Columbia University, April 19, 1955.

This study was limited to ten state normal schools in the four state area of New York, Connecticut, Massachusetts, and Rhode Island; to the period from 1839 to 1900; and to the goals, methods, and content of the various sciences in these institutions. The method was a historical analysis of all pertinent materials which could be obtained. The investigator visited each institution and such libraries as the Widener of Harvard, Massachusetts Historical Society, New York State, etc. At the majority of colleges and at several libraries, he was able to find extensive manuscript and primary materials—student notebooks, lecture notes, lists of apparatus, photographs, and letters—which afforded him a rich supply of source materials. It was on these which the investigator leaned, rather than on catalog data. Statements and conclusions are to be applied only to the institutions studied.

(Mass.), taught zoology, physiology, and natural philosophy to the brave handful of girls who were the first state normal class. Within the next few years, he worked his second and third term matriculants systematically through the whole range of the sciences—from astronomy to zoology.

Cyrus Peirce, and his successors for the next two decades, believed that science had become an accepted part of society and that the man or woman called to the common schools should, as a matter of course, be exposed to the rudiments of the sciences. These pioneers did not conceive of the subject matter of the sciences as elementary school branches. Merely to train teachers for the common branches was as much of a task as the normals could permit themselves.

Physiology was an exception, because the normal schools were anxious to make it part of the elementary school curriculum. Therefore, it was usually taught in the first term so that those who left after a few weeks or months would have been exposed to some of its precepts. Physiology was accepted both as a practical and a professional branch because it was thought to result in better student health at the normal school (an important consideration when term after term was marked by the death of students from such diseases as consumption and typhoid fever), and in the common school soon to be presided over by the normalite. Moreover, the subject matter was expected to contribute to the attainment of the other goals of normal science. A factor conditioning the status of physiology seems to have been its acceptance by many common school teachers as part of their curriculum, long before any other areas of science were even advocated by normal school men for inclusion in the elementary grades.

Shortly after the Civil War ended, the curriculum was extended to two years, and in several states, the ambitious student was allowed to remain for another two years of advanced study. This expansion resulted in a general requirement that each of eight sciences be studied: astronomy, botany, chemistry, geology, physical geography, physics, physiology, and zoology. More often than not, zoology and chemistry were scheduled for the first semester because they were assumed to be basic to the other sciences. That is, zoology paved the way for a thorough understanding of physiology; chemistry buttressed all. The scheme differed for each institution in a fashion reminiscent of the modern college, and for probably the very same reasons.

In terms of class time, every member of the two year program spent some ten to twenty weeks (four-five meetings each week) in each course. To contrast this with modern practice, it is evident that a ten week course, meeting for a total of fifty sessions, is easily the equivalent of a semester course meeting three times a week for sixteen weeks. Chemistry, physics, and physiology classes commonly met for twenty weeks, the others for ten weeks. In terms of class time, the sciences were surely more important elements in those 19th century normal schools which were investigated than in the teachers colleges of today. Educators who would add to the science requirements of the teachers college are advised that they are following a trail which was blazed some ninety years ago and then forgotten.

Purposes of Normal School Science

Throughout the 19th century, the objectives of normal school science were very much like those of the academies and high schools. Both the normal and secondary schools believed that science was a powerful instrument for building a firm belief in God. Both were certain that science would better prepare students for the practical world of everyday life; both insisted that science sharpened powers of perception, memory, generalization, and reason. This is to be expected. The science teacher could not help but absorb the psychological and educational folklore of the day. He knew that science, when taught by "right method" automatically resulted in achievement of

desired goals. The normals, therefore, were certain that the field of science was a necessary element in educating teachers who feared God, yet understood the rationale of the God-belief; who loved "Nature"; and were so well trained scientifically that they understood and appreciated the role of science in their rapidly expanding economy.

The significant difference between the normal schools and the academies did not lie in these goals, so briefly described above. It existed in the major purpose of the normal schools, a purpose which continued unchanged from 1839 to the turn of the century—the preparation of competent teachers for the common schools. The other aims were valuable accessories for the proper "culture" of the teacher. Indeed, only by attaining these aims could the teacher realize his full potentialities, but they were to be attained only because he would thereby become a better teacher and for no other reason. The concept of the teacher as a citizen and thereby a person entitled to a well-rounded education, irrespective of whether or not he is to teach, played a minor part in normal school thinking. In other words, the "general education" program of the normal schools, in the sense of non-professional training, was a narrowly oriented program. Its *raison d'etre* was simply this: the teacher whose education comprehended the sciences was "obviously" preferable to the teacher unschooled in the sciences.

The reasons which the normal schools advanced for their science requirements are, with the two exceptions of theology and general education, basically those of the modern teachers college. The phraseology may differ—the underlying psychology is no longer the same, but the vision of the wonders to be wrought by the systematic study of science is unchanged, even to the profound trust in the methods of science.

For a period of some twenty years, the normals made little or no attempt to press for science in the elementary school curriculum. With the advent of the sixties and its strong Pestalozzian currents, the normals turned their attention to the problem of developing both the willingness and competence to teach science in the common schools. They were well aware that the great majority of boys and girls would never enter the high schools to study formal science and that, if mass understanding and appreciation of science was vital for the citizen, science must become both respected and expected in every common school.

In the attempt to squeeze science into the common branches, normal school science men undertook a propaganda campaign which continued to the end of the century. They wrote voluminously; spoke frequently at institutes and summer schools; and prepared simple courses of study. Elementary science was required by administrative fiat in many school systems and encouraged by the various state boards of education. Connecticut even required all applicants for state certification to pass a written test in elementary science.

The normals realistically took their own students as they were. Their methods and content were professionalized for the common schools. They circumvented the inevitable excuse that the lack of science materials in the schools would prevent their students from making use of their scientific knowledge. This was done by requiring students to become proficient enough in handling tools to manufacture equipment sufficient for their needs. For some two decades, virtually every normal student graduated with a supply of materials for each area of elementary science, or with some idea of how to prepare, in-service, whatever was necessary. The modern teachers college has hardly begun to think in terms as functional as this.

The Centrality of Method

The normal schools were not content to let the matter rest with massive doses of science. The *leit-motif* of professional preparation drove them to revise the traditional methods of presenting subject matter simply because these methods were incapable of preparing the kind of teachers

that Horace Mann and his colleagues demanded.

Cyrus Peirce, for example, guided his students through "teaching exercises" which revealed their grasp of subject matter and simultaneously trained them pedagogically. This professional exercise was the distinctive method of the first two decades of the normal movement, at a time when the teacher-directed textbook recitation prevailed throughout the land. The pure textbook recitation was seldom found in the normals, and it was the student who did much of the questioning when it was employed.

Judging from a "cover the text" point of view, classes moved slowly, yet the teaching exercise undoubtedly contributed to learning because of its repetition. "Overlearning" resulted because science was taught by imitating teachers—as exact an imitation as possible. This science was not to be taught in the elementary school—but, nonetheless students learned science by teaching science to their classmates.

The value of the science teaching exercise may be questioned even when, as so often happened, the class pretended to be children. It was, nevertheless, the first professional invention by normal school men, and survived in one form or another in several of the normals until the end of the century. Throughout that century, the professionalized methods of the normal schools were to contrast sharply with the conventional procedures of the secondary schools. They were to diverge even more when Pestalozzian ideas were harnessed by the Westfield (Mass.) Normal School in the late fifties.

Pestalozzi had, of course, insisted on the primacy of concrete experience in learning. Mr. Peirce and his co-workers, years before the Westfield experiment, were also well aware of the importance of first-hand learning, and, particularly in the physical sciences, had frequently resorted to lecture-demonstrations, both instructor and student. These "experiments" were traditional—the class was told the object of the experiment, and the procedure; the class merely verified the results. This was learning via concrete experience, but it appears to have been as unsuccessful then as it is today.

The normals were cognizant of this, as well as of other deficiencies in their methods of teaching science, and as a result of this awareness, the teaching of science in the normal schools was revolutionized when John W. Dickinson of the Westfield Normal formulated his "Analytic-Objective" methodology in the late fifties. The "new" method dominated normal science, in one guise or other, until the advent of Herbartianism in the last few years of the 19th century. In essence, Westfield sought to implement Pestalozzi's ideas by selecting science as an excellent starting point. The basic idea of the movement was that science must be taught inductively; textbooks were to serve only as reference sources. Vast collections of scientific materials were required in order to make possible this heuristic approach, and a collecting fever gripped the normals, resulting in enviable museums and laboratories.

What was new and fresh, however, soon hardened into a rigid formalism. The inductive strengths were weakened by an artificial scheme of outlining topics in which the teacher replaced the text. The study of science had also, at about this time, become a desirable element of the elementary school curriculum, and each normalite was taught an exact technique which promised success. Unfortunately, this science was no longer the science which Dickinson had first visualized.

In the early eighties, soon after the normals had installed laboratory facilities for individual work, the "Analytic-Objective" method was thoroughly overhauled. The Bridgewater (Mass.) Normal led the movement away from stereotyped methodology to a new, creatively inductive experience. Its contribution, of major importance to us today, was a deliberate heuristic over-emphasis. Only by deriving all possible science learning from individual

observation and experiment was it possible for each learner to become an experienced observer and reasoner—so ran the Bridgewater argument. The men who conceived the new plan were positive that the method of science had now become an easily worked tool in the hands of the embryo teacher. They were profoundly impressed by the results of scientific investigation in the booming eighties and nineties and were convinced that they had at long last, invented a modern "philosopher's stone."

In order to utilize inductive principles most effectively, the normals divided science courses into two parts; one, "elementary" and the other, "scientific." The former, designed as a course of study for elementary school science, sought to build a solid foundation of scientific fact on first hand experience. The "scientific" course was intended to prepare for teaching in the higher grades and the high schools, but it was nearly always required of elementary students who were thus allowed to make use of their newly acquired perceptive powers in order to develop the higher faculties of the minds. It was in the "scientific" courses that abstract theory and principle were derived from the learnings of the "elementary" courses.

This particular device was peculiar to the normal schools, and it illustrates the devices by which they tried to attain their goals. Their sister institutions, the high schools and academies, relied on the time-tested methods of the past. They, too, were aware that concrete experience was vital to real learning. But, and an important *but,* they made no effort to apply heuristic ideas in science classes. To point up the differences in implementing goals, all of the normal schools required individual laboratory work in each science during the last two decades of the 19th century. On the other hand, only the very largest secondary schools were similarly equipped, and these few were guided by the college belief that skill in scientific thinking grew automatically from the conventional academic experiment or demonstration. Unfortunately, that experiment merely *illustrated* scientific law or fact, and it is precisely this kind of experiment which all too often is part of college laboratory instruction today.

The normal schools committed numerous errors in their attempts to build an inductive curriculum. They were, however, earnestly attempting to attain their goals by means which they believed proper, and researchers in the methodology of science teaching should not neglect their efforts.

Evaluation of Accomplishment

Evaluation is difficult, and evaluation of the achievements of normal school science is no exception. Obviously, it must be made in terms of the aims which were set forth by the normal schools, and of their success and failure in attaining those aims.

If we turn to the introductory questions, the evidence supporting a comprehensive and conscientious science program is most impressive. Final judgment should not rest merely on the number and variety of scientific facts studied for the reason that the continual insistence on mastery of professional techniques allowed time for fewer facts of science to be "covered" than one might have expected. The important point is the extent to which these particular facts were mastered by methods designed specifically for the purpose. The author was able to study many dozens of student notebooks, test papers, laboratory manuals, and other evidences of student achievement, and the silent evidence of these materials convinced him that normal school science instructors were successful in building real understanding of the limited materials studied. Student notebooks in particular were most impressive as a testimonial to the time and effort which went into each science course, particularly after the advent of the laboratory.

The critic may well point out the limitation of normal science to "elementary" facts and to those principles which could be derived from "elementary" facts. Perhaps the most serious weakness was inherent in the avoidance of mathematical treatment

which resulted in a descriptive and classificatory science. It should be clear, however, that these "weaknesses" were deliberately created and maintained—mathematical theory was never believed to be essential for common school teachers.

The quality of the teaching was such that the writer was continually surprised, often amazed, and usually gratified. Consider such factors as these: the conventional two-year program of the last third of the century was crammed with some twenty-five to thirty-five courses; students were unprepared for a normal school science which was taught by time-consuming inductive and experimental procedures; most courses depended on repetitious teaching exercises; and finally, the largest part of the science course was purposely designed for the elementary schools.

The wonder is not that science was "elementary," but that so much was accomplished. Normal science was far more than a perfunctory textbook study. It was personal experience with the vital storehouse of nature. It could so easily have been stultifying and worthless because of what appear to have been hopeless odds. In terms of their goals, the normals must be judged to have achieved part of what they had set out to do. If mastery of the method and content of science as set forth by the normals is accepted as evidence of scientific literacy, then graduates of the normals *were* scientifically literate.

There are abundant materials which testify to the superior teaching ability of the normal-trained teacher. He occupied the better paid and more responsible positions because he knew exactly how to proceed, what to teach, how to discipline, and what to expect. This was considered to be a natural outcome of normal school teaching. After all, was it not logical to expect that the person trained in the sciences would, all other things being equal, be a superior teacher? Even if he taught no science in the elementary school, his science training was expected to reap rich rewards for him nevertheless.

Objective evaluation of this particular claim is difficult. Science educators would surely agree that such results are to be hoped for, and the writer is inclined to agree with the claims of the normal schools that their scientific training helped teachers in their school pursuits whether or not science was taught.

Surely, it would seem that the normal schools prepared their students as thoroughly and functionally as possible for the teaching of science. And yet, a necessary catalyst must have been missing. Science simply did not take in the common schools. There are dozens of cases of omission, of failure, and of abandonment of required elementary school science for every individual success. Indeed, the successes seem to have been due to individuals who would have taught science, whether or not they had been so trained in the normal schools.

The failure of non-normal trained personnel is understandable. But the avoidance of science by the normal graduate, undoubtedly a superior teacher, can be explained only by assuming that neither the interest to teach science nor the desire had been aroused. The machinery had been set up, the operators were expert, but were unaccountably reluctant to press the starting button.

There are many factors which may have contributed to their inertia. For example, good science teaching then, as today, was time-consuming and almost impossible with large classes and large, ungraded classes were the rule. Administrative reluctance was *not* a factor. Even in communities whose educational authorities were anxious to make science part of the curriculum and supplied money, time, and competent supervisory help, there were the same failures and omissions.

Because of this, some responsibility must rest on the normal school graduate, and ultimately with the normal schools which had failed to convince their students that science should no more be omitted from the common school than arithmetic or geography. It is more than conceivable that,

despite the attention to science, normal school students were insecure and afraid. Perhaps both the range of subject matter demanded of them and the requisite skills were just too much to be developed in two years.

There appears to be no other hypothesis capable of explaining why the normals failed to secure more than a toe-hold on this particular goal. The point becomes even more pertinent when we recall the emphasis on scientific method to which normal science teachers had turned in their effort to enable students to master by themselves what there was too little time for in the normal schools. This also was a chimera.

There were several other phenomena which affected the quality of normal school science. Strangely enough the normals were unwilling to teach science and did so only because students were not science-qualified in the light of their progressive ideas. Ideally, the common schools and high schools were to have prepared their graduates so that the only function of the normals was to have been professional training. That this millenium never occurred is illustrated by the failure of the New York State Normal College (Albany) in the early nineties in its attempt to eliminate subject-matter courses. Reliance on high school subject-matter competence was altered in a few years by the inclusion in the curriculum of required science courses for all high school graduates.

The facts are plain. Students entering the normals whether products of the elementary or secondary schools were not prepared in science nor for science teaching. The common schools did not then as they do not today, make science a part of their curriculum—a most important point, because, until the last few years of the century, the normalite was more often than not a product of the common schools, with no formal high school study.

Even secondary school graduates were unqualified when viewed with normal school eyes. Most of them were exposed to one or more formal courses in science . . . they were, that is, unless they were enrolled in the academic curriculum. Those who attended the larger high schools had probably struggled through a few weeks of laboratory practice (the smaller schools could not afford the luxury of first-hand experience), which was all too often a dull, formalistic chemistry or physics, minus the vitality and heurism of normal school science. Boys and girls who knew only memorizing of textbooks, who weighed and dissected only to illustrate what they had previously known, were completely unprepared for two years of study in which textbooks were resorted to only after students were unable to answer questions by laboratory procedures.

As a result, the normal schools had accepted this stern reality— entering students must be taught science from the ground up. Science was really forced into their curriculum and took up nearly one-third of all class time for this reason. The normals had no other alternative than to build a strong science-centered program. But, because of time limitations, they also had no alternative to a simple science, uncomplicated by mathematics and abstractions.

If all these points are taken into consideration, and if the elementary school science goal is excepted, the science program must be judged to have functioned more or less as intended, and normal school science achievement is thereby far more impressive and successful than the casual student of normal school history would suppose. The products of the normal schools were scientifically literate in terms of their background, training, and environment. They were better equipped to meet their professional responsibilities regardless of whether or not science was actually taught in the common schools. The faith which Horace Mann placed on the value of normal training would therefore seem to have been abundantly justified by the teaching of science in the 19th century normal school.

PROGRAM
OF
NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING

Twenty-Eighth Annual Meeting

APRIL 18, 19, AND 20, 1955

Teachers College, Columbia University

OFFICERS OF THE NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING

President—Kenneth E. Anderson, Dean of the School of Education, University of Kansas, Lawrence, Kansas

Vice-President—William C. Van Deventer, Department of Biology, Western Michigan College of Education, Kalamazoo, Michigan

Secretary-Treasurer—Clarence M. Pruitt, University of Tampa, Tampa, Florida

Executive Committee Members—

Waldo W. E. Blanchet, Dean, Fort Valley State College, Fort Valley, Georgia

George G. Mallinson, Director of Graduate Studies, Western Michigan College, Kalamazoo, Michigan

PROGRAM

Monday, April 18, 1955

Registration and Coffee Hour—Grace Dodge Room, 8:30 A.M.–9:30 A.M.

I. Program for Graduate Students and Members—Presentation and Discussion of Research Studies in Progress......................9:30 A.M.–11:15 A.M.

Horace Mann Auditorium

J. Darrell Barnard, *Chairman*, Chairman of the Department of Science Education, New York University

1. *Improving the Quality of Educational Experiences of Junior High School Students*
   George J. Pallrand, Science Teacher, Riverdale School for Boys, New York

2. *The Development of a General Education College Chemistry Course Which Incorporates a Modern Philosophy of Science and Is Based Upon a Modern Concept of the Atom*
   L. A. ARNOLD, University of Florida, Gainesville, Florida

3. *A Comparison of a Specific Problem-Solving Method, Involving Experiments, with a Lecture-Demonstration Method of Teaching a Course in Physical Science*
   CHRISTOPHER D. RAFTER, Danbury State Teachers College, Danbury, Connecticut

4. *Summary and Recommendations*
   BENJAMIN C. GRUENBERG, Author and Consultant in Science Education, New York City

II. Needed Research in Elementary Science Teaching.......11:15 A.M.–1:00 P.M.

SAMUEL SCHENBERG, *Chairman,* Supervisor of High School Science, New York City Board of Education

1. *What Have Been the Major Emphases in Research in Elementary Science During the Past Five Years?*
   JACQUELINE BUCK MALLINSON, Chairman, Elementary Level Committee, NARST

2. *How Can Science Learning Be Incorporated into the Elementary Curriculum?*
   PAUL E. BLACKWOOD, Specialist for Elementary Science, United States Office of Education

3. *How Can the Grade Level for the Introduction of Science Concepts Be Determined?*
   MARTIN L. ROBERTSON, Executive Editor of the Educational Department, Macmillan Company

4. *On What Bases Should Science Learning Materials Be Selected on the Elementary Level?*
   HARRY MILGROM, Supervisor of Elementary Science, New York City Board of Education

5. *How Can an Effective In-service Program Be Evolved to Meet the Science Needs of Elementary Teachers?*
   ROSE LAMMEL, Professor of Science Education, New York University

6. *How Can the Elementary Science Program Reveal, Nourish and Maintain Science Talent?*
   N. ELDRED BINGHAM, Professor of Education, University of Florida

7. *Summary*
   ETHEL F. HUGGARD, Associate Superintendent of Curriculum Development, New York City Board of Education

III. Science Education in New York City..................2:15 P.M.–4:45 P.M.

JEROME METZNER, *Chairman,* Chairman of the Department of Biology and Introductory Science, Bronx High School of Science, New York City

1. *Science in the Elementary and Junior High Schools*
   HARRY MILGROM, Supervisor of Elementary Science, New York City Board of Education

   ALFRED D. BECK, Supervisor of Junior High School Science, New York City Board of Education

2. *High School Science*
   Biology—JEROME METZNER, Chairman of the Department of Biology and Introductory Science, Bronx High School of Science, New York City

   Chemistry—SAUL GEFFNER, Chairman of the Department of Chemistry, Far Rockaway High School, New York City

   Physics—THEODORE BENJAMIN, Chairman of Department of Physical Science, DeWitt Clinton High School, New York City

3. *Vocational High School Science*
   NATHAN CLARK, Science Supervisor, Vocational High School Division

4. *College Science*
   ABRAHAM RASKIN, Associate Professor of Physiology, Hunter College, New York City

   NATHAN S. WASHTON, Professor of Education, Queens College, Flushing, New York

TUESDAY, APRIL 19, 1955

Horace Mann Auditorium

IV. Science Education in Foreign Countries................9:00 A.M.–10:30 A.M.

WILLIAM C. VAN DEVENTER, *Chairman,* Department of Biology, Western Michigan College of Education

1. EARL R. GLENN, United States Foundation in the Philippines
2. E. LAWRENCE PALMER, Director of Conservation Education, National Wildlife Federation
3. ELWOOD D. HEISS, New Haven State Teachers College
4. VERNON C. LINGREN, School of Education, University of Pittsburgh

V. Research Papers................................10:30 A.M.–12:15 P.M.

WILLIAM C. VAN DEVENTER, *Chairman,* Department of Biology, Western Michigan College of Education

1. *Characteristics of Superior Science Students*
   ROBERT D. MACCURDY, Senior High School, Watertown, Massachusetts
2. *A Study of Selected Interest Factors as Related to Outcomes of the Program of General Education at Michigan State College*
   VICTOR HOWARD, Michigan State College
3. *An Analysis of the Process by Which a Group Selects or Rejects Ideas or Beliefs*
   CHESTER A. LAWSON, Michigan State College

4. *Reading and Demonstration in Science Teaching*
CLARENCE H. BOECK, College of Education, University of Minnesota

VI. Research Papers....................................1:30 P.M.–3:00 P.M.

WILLIAM C. VAN DEVENTER, *Chairman*, Department of Biology, Western Michigan College of Education

1. *Prediction of Achievement in Junior High School Science*
C. MICHAEL ADRAGNA, School of Education, New York University
2. *Science in Nineteenth Century Normal School*
LOUIS KUSLAN, New Haven State Teachers College
3. *The Effect of Differential Reinforcement on Concept Formation*
FINLAY CARPENTER, Michigan State College
4. *An Experimental Study Applying Non-Aristotelian Principles in the Measurement of Adjustment and Maladjustment*
THOMAS M. WEISS, Michigan State College

VII. College General Education Science Programs in Action....3:00 P.M.–4:00 P.M.

WALDO W. E. BLANCHET, *Chairman*, Dean, Fort Valley State College, Fort Valley, Georgia

1. CLEMENT L. HENSHAW, Colgate University
2. CHESTER A. LAWSON, Michigan State College
3. WILLIAM C. VAN DEVENTER, Western Michigan College of Education

WEDNESDAY, APRIL 20, 1955

Room 256—Thompson Hall

VIII. Business Meeting................................9:00 P.M.–11:30 P.M.

KENNETH E. ANDERSON, *Chairman*, Dean of the School of Education, University of Kansas

1. *Review of the Activities of the Association*
KENNETH E. ANDERSON, Dean, School of Education, University of Kansas
2. *Affiliation with the American Association for the Advancement of Science*
GEORGE G. MALLINSON, Director of the Graduate Studies, Western Michigan College
3. *Third Annual Review of Research in Science Education*
HERBERT A. SMITH, Director of the Bureau of Educational Research and Service, School of Education, University of Kansas

4. *Business Report*
   CLARENCE M. PRUITT, Secretary-Treasurer, University of Tampa

IX. Annual Luncheon of NARST *Horace Mann Cafeteria*..............12:15 P.M.

Address: CRITICAL THINKING AND RESEARCH, GORDON M. DUNNING

THIRD ANNUAL REVIEW OF RESEARCH IN SCIENCE TEACHING

Chairman--HERBERT A. SMITH, Director of the Bureau of Educational Research and Service, School of Education, University of Kansas, Lawrence, Kansas

Vice-Chairman—NATHAN S. WASHTON, Professor of Education, Queens College, Flushing, New York

Level Committee Chairmen:

1. Elementary School Committee
   JACQUELINE BUCK MALLINSON, *Chairman*, Formerly, Science Instructor, Gross Pointe Public Schools, Gross Pointe, Michigan

   DONALD ALLEN BOYER, *Vice-Chairman*, Head of the Science Department, Winnetka Public Schools, Winnetka, Illinois

2. Secondary School Committee
   CLARENCE H. BOECK, *Chairman*, Head of the Science Department, University High School, University of Minnesota, Minneapolis, Minnesota

   WILLIAM B. REINER, *Vice-Chairman*, New York City Board of Education, Brooklyn, New York

3. College Level Committee
   THOMAS P. FRASER, *Chairman*, Department of Science Education, Morgan State College, Baltimore, Maryland

   CLARENCE H. NELSON, *Vice-Chairman*, Michigan State College, East Lansing, Michigan

Committee on Educational Trends in Science

Co-Chairmen—JEROME METZNER, Chairman of the Department of Biology and Introductory Science, Bronx High School of Science, New York City

ABRAHAM RASKIN, Associate Professor of Physiology, Hunter College, New York City

Committee on Membership

CYRUS W. BARNES, *Chairman*, School of Education, New York University

Committee in Charge of Local Arrangements for the Annual Meeting

HUBERT M. EVANS, *Chairman*, Professor of Natural Sciences, Teachers College, Columbia University, New York City

A REPORT OF THE FUTURE SCIENTISTS OF AMERICA FOUNDATION OF THE NATIONAL SCIENCE TEACHERS ASSOCIATION *

Nathan S. Washton

Queens College, Flushing, New York

One of the major problems facing scientific industries and the teaching profession is the recruitment of prospective science teachers and scientists. There is an acute shortage of scientists and science teachers. The number of college majors in science and mathematics decreased in serious proportions during the past few years. Throughout the nation there are many teachers who are not adequately prepared to teach in these areas. The Future Scientists of America Foundation of the National Science Teachers Association requested representatives from many professional teaching societies, scientific societies, and leading industries to discuss this vital problem.

The Future Scientists of Amercia Foundation in cooperation with scientific, educational, and industrial organizations are attempting to solve this problem. High school students who are talented in science or mathematics are encouraged to do creative projects, exhibits, experiments, and reports. They may submit and exhibit their results to local science fairs and meetings. Many prizes such as government bonds, medals, and scholarships are awarded to successful contestants. High school science teachers play an active role in encouraging and guiding these students to study specific problems in science and mathematics. It is believed that this kind of program will stimulate further interest in and knowledge of the natural sciences. Thus, many high school students are given an opportunity to specialize as potential scientists or science teachers when they enter college.

Another successful program was reported that dealt with enriching the background and experience of a number of high school science teachers. Several scientific industries employed many of the science teachers for one month during the summer. The teachers were paid one-tenth of their annual salary. They made a worthy contribution to the industry, and the science teachers were able to comprehend the applications of science in industry more effectively. It was said that most of these science teachers returned to their classes with an inspiring point of view and a deep appreciation of science and industry.

Several suggestions were made to improve the recruitment of science teachers and scientists. Better communication between local, professional, scientific societies and industries where money might be available to support such programs as scholarships, employing high school science teachers during the summer months in industries, offering tuition-free fellowships and scholarships to high school science teachers during the summer months, to encourage many people in industry to send out speakers in related scientific industries who could stimulate young people to consider science teaching and science industry as a possible career, were some of the recommendations that came from the group. Legislation was also suggested as a possibility. Perhaps the state certification of science teachers should be changed so that obsolete laws will no longer permit those who are unqualified to teach the sciences.

* Second annual conference held September 23, 1954 in the National Education Association Building, Washington, D. C. Nathan S. Washton was representing NARST at this conference.

Paper presented at Twenty-Eighth Annual Meeting of the National Association for Research in Science Teaching, Teachers College, Columbia University, April 20, 1955.

Another recommendation was the improvement of the science laboratory. The major problem of the group attending this conference was to raise money to support their program in organizing future scientists of America clubs throughout the nation. Many industries have cooperated in this venture but the financial support is still lacking.

The writer believes that there are implications for research work that may be undertaken by a cooperative group sponsored perhaps by NARST in connection with one of the foundations which may be able to support such scientific research. Such research could be cooperative between NARST and the NSTA. The problems for research may be developed along the following lines: (1) What makes a person want to be a scientist or a science teacher? Perhaps a cooperative program of research investigating the various factors responsible for a person seeking a career as a scientist or a science teacher may be helpful in this program. There are various ways in which this research work could be approached. For example, one may begin by examining successful scientists and successful science teachers to find out what in their background or in earlier training or experiences influenced them the most in becoming a scientist or a science teacher. Another approach might be to begin with youngsters perhaps in the junior high school to find out where their interests are or where they may be lacking in the sciences. What are the causes of such lack of interest in the sciences? Is it due to the individual's earlier experiences in the elementary school, at home, intelligence, socioeconomic background, religious point of view, and many other factors? It seems impossible for any one person to undertake a study of this kind. However, if a team of experts would investigate the various factors and if such money could be made available by a national foundation, it is possible that some interesting data to help solve this problem could be obtained.

A second study for research that would be of interest to this group, although it was not suggested as such, would be the attitude of teachers towards industry. In view of the fact that a few industries in the sciences have employed high school science teachers during the summer months, what impact was made upon these teachers? How, if at all, does the program enrich the science teacher's background to do a more effective job in the classroom and to encourage and to inspire young people to consider science or science teaching as a career? Although in the course of discussion at this meeting several people indicated that all the attitudes were positive it would be worthwhile to make a very objective study to seek out what negative attitudes might prevail, if any.

A third area of study might be to find out why students don't go on to college, especially where the sciences are concerned. Many studies have already appeared in this area. It might be necessary to have a group of research people correlate the various findings and then come up with another integrated scheme of finding out other possible factors.

A fourth problem for research might be, when is it feasible to recruit young people to consider science and science teaching as a career? Several suggestions were made. Some people believed it should begin with the secondary level; others insist it must begin specifically at the junior high school 7th grade. A few believe it should begin with the elementary school. What kind of guidance is administered in the public schools that affects the recruitment program of prospective scientists and science teachers?

Careful study should be given to the proposal, if money is given by a commercial, scientific organization, what is the responsibility or obligation or control, if any, that may influence the secondary school curriculum? Where money is obtained, people usually expect something in return. Wherein lies the line of demarcation, if

there is such a line, between the relationships of support from industry and control by industry in terms of the science program of instruction? Perhaps this problem would be worthwhile for further study.

It is obvious that scientific industries are offering higher salaries than the science teachers receive. It does not seem likely that both of these will be equalized. However, it appears that there is too great a difference in salary which may be one of the factors responsible for the lack of an adequate supply of students who may consider science teaching as a career. This could account for the teacher shortage in all areas. Hence, it was proposed that teacher salaries be increased.

Unless we obtain highly qualified and competent science teachers, we cannot hope for a better science teaching program which would inspire a good number of young people to consider science as a career. We must have eager and top-notch science teachers to help develop top-notch scientists. It is not suggested that all students should become scientists. The high school science teacher should encourage young, "budding" scientists to take advantage of the many opportunities that are offered by the Future Scientists of America Foundation in cooperation with industries.

Science teachers should also re-examine the curriculum and the resources that are used to implement science teaching. How are community resources (field trips, industry, museums, science and health agencies, etc.) being used if at all? Should certain areas of science be emphasized and others deleted? Why are we teaching all of the areas in science? Do they help us develop our purposes? What is the role of the laboratory? Are "cookbook recipe" type of experiments providing the best stimulation for further interest and knowledge of science? Is general science the best kind of science course for all students or some students in the ninth year? What articulation occurs before and after the ninth grade science course? How does the science teacher evaluate interests, attitudes, and skills in pupil learning? Are there adequate reading materials available to pupils for further study? What provisions are made for in-service growth of science teachers? How are they informed of the latest research work in teaching science? What would happen to the classroom teachers' instruction and how would it affect learning, if science teachers put into practice the worthwhile findings produced by research specialists in science education? This critical examination of the science program is essential and will determine whether we inspire young people to learn science or whether we kill the interest in science.

A REPORT TO THE NARST ON THE RELATIONSHIPS WITH THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE FOR THE YEAR 1954–55 *

GEORGE GREISEN MALLINSON

Western Michigan College, Kalamazoo, Michigan

INTRODUCTION

UNTIL the year 1954–55 the National Association for Research in Science Teaching had only one regular relationship with the American Association for the Advancement of Science, namely, membership on its Cooperative Committee on the Teaching of Science and Mathematics. On an irregular basis the NARST co-sponsored various sessions on science education research at the annual convention of the AAAS.

However, during the past five years the NARST has grown steadily in member-

* Report made by NARST Representative on Cooperative Committee at the Twenty-Eighth Annual Meeting of the National Association for Research in Science Teaching, Teachers College, Columbia University, April 20, 1955.

ship and function. Of the two, the latter is by far the more important. For the last three years the NARST has published annual reviews of science education research replacing those discontinued by the American Educational Research Association. Further it has participated in a wider variety of meetings with other national societies interested in various aspects of science teaching.

As a result, it was believed that a broader affiliation with the AAAS would be more desirable. Hence within the past year the NARST became an affiliate of the AAAS, appointed a representative to the AAAS Council, and initiated symposia on science education research at the Berkeley Convention in 1954 and Atlanta Convention in 1955. These symposia attracted many co-sponsors from other national societies.

Hence the annual report of your representative now encompasses these new activities in addition to those with the Cooperative Committee. For convenience, this report is divided into three sections, (a) Activities with the Cooperative Committee on the Teaching of Science and Mathematics of the AAAS, (b) Affiliation with the AAAS, and (c) Symposia on Science Education Research at the AAAS Conventions.

ACTIVITIES WITH THE COOPERATIVE COMMITTEE ON THE TEACHING OF SCIENCE AND MATHEMATICS OF THE AAAS

Meetings of the Cooperative Committee

Since the last meeting of the NARST the Cooperative Committee has met on three occasions, namely, (1) at the Hotel Morrison, Chicago, Illinois, April 3 and 4, 1954; (2) at the National Education Association Building, Washington, D. C., on October 14, 15 and 16, 1954; and (3) at the Conrad Hilton Hotel, Chicago, Illinois, February 25 and 26, 1955. The place of the meeting is in accord with the policy of meeting in Washington in the Fall and in the Midwest in the Spring. The cost of your representative's attendance at the meetings was born by sources other than the treasury of the NARST.

Personnel of the Cooperative Committee

During the past year there were a number of changes in personnel. The following members of the Committee were replaced:

a. Donald W. Lentz—Central Association of Science and Mathematics Teachers
b. Duane Roller—Board of Directors of the AAAS
c. Francis D. Curtis—Section Q, AAAS
d. John R. Mayor—Mathematical Association of America
e. Glenn W. Blaydes—Botanical Society of America
f. George E. Hawkins—National Council of Teachers of Mathematics
g. Bernard B. Watson—American Association of Physics Teachers

At the meeting at the Conrad Hilton Hotel the personnel of the Committee was as follows:

John R. Mayor, Chairman
Bernard B. Watson, Secretary
(These two persons retained membership on the Cooperative Committee as officers although they had been replaced as society representatives)
Fletcher G. Watson—American Association of Physics Teachers
Wasley S. Krogdahl—American Astronomical Society
C. H. Sorum—American Chemical Society
Arthur L. Howland—American Geological Institute
J. W. Buchta—American Institute of Physics
Richard L. Weaver—American Nature Study Society
L. V. Domm—American Society of Zoologists
Harold K. Schilling—Board of Directors, AAAS
Fred H. Norris—Botanical Society of America
W. H. Edwards—Central Association of Science and Mathematics Teachers
Laurence L. Quill—Division of Chemical Education of the American Chemical Society
David Blackwell—Mathematical Association of America
Prevo L. Whitaker—National Association of Biology Teachers
George G. Mallinson—National Association for Research in Science Teaching
Henry W. Syer—National Council of Teachers of Mathematics
Morris Meister—National Science Teachers Association
Harold E. Wise—Section Q (Education), AAAS

It is interesting to note that despite distances and many responsibilities both teaching and administration, the attendance

of the representatives is excellent. This may have been stimulated by a recent action taken by the Committee. At the Washington meeting on Saturday October 16, 1954 the following resolution was passed:

"That a member society be notified when its representative has been absent from two consecutive meetings of the Committee and that the society be asked to name a new representative when three consecutive absences have been incurred." However, even before this resolution, with few exceptions, attendance had been excellent.

Officers of the Cooperative Committee

The election of officers of the Committee has generally involved the approval of the slate presented by the Nominating Committee that is appointed by the chairman. No basic policy had been established for election or succession to office. As a result the burden of organizing meetings fell almost completely on the shoulders of one person. This burden is a great one. During a period of six years in which your representative has functioned only two persons have been chairmen, namely, K. Lark-Horovitz and Morris Meister. Further, the reign of Lark-Horovitz extended several years prior. This is not a suggestion that their services had not been meritorious, because they had. However, the lack of a basic policy for succession would have made the naming of a new chairman by the Nominating Committee tantamount to a criticism.

Consequently a proposal prepared by your representative for the reorganization of the administrative structure of the Cooperative Committee was examined. After some discussion the following motions were made and approved:

1. That the office of vice-chairman be added to the existing offices of chairman and secretary.

2. That there be an executive committee consisting of the three officers.

3. That the chairman and secretary be elected for two year terms with the chairman to be elected in even years and the secretary in odd years; and that the vice-chairman serve for one year.

The officers for 1954–55 on the basis of this policy were Chairman, John R. Mayor; Vice-chairman, Laurence L. Quill; and Secretary, Bernard B. Watson. For the 1955–56 year, the officers are Chairman, John R. Mayor, Vice-chairman, J. W. Buchta; and Secretary, Bernard B. Watson.

Your representative believes that this new policy will result in a more equitable sharing of responsibility.

Activities of the Cooperative Committee

As stated in previous reports your representative has been most concerned with the activities and functions of the Cooperative Committee. He has believed that they have not been focussed on vital problems that the available time and effort of the Committee could possibly bring to fruition. Further, many meetings have been devoted to topics that were of major interest to one or two members of the Committee only. Also, from meeting to meeting there had been little or no liaison among the Committee members. As a result the Committee activities became for all practical purposes biannual discussions that were quickly forgotten.

However, the stature of the Committee and its potentialities cannot be underestimated. Society after society, group after group, and person after person have submitted for endorsement projects over which the Committee would have had no control. It is salutary to note that with trivial exceptions, the requests have been turned down. Thus, the Committee has not, in effect, become a "professional endorser." An examination of the minutes (distributed at the NARST Convention) will point out the situation just described.

Many other minor activities were undertaken also, most of which are described in the minutes. They are not of sufficient import however to be mentioned here.

So far in this report, the activities seem to be viewed with pessimism. It would be in error however to leave the NARST members with that impression. At the

last three meetings, the Committee with the cooperation of the administrative officers of the AAAS has undertaken what your representative believes to be a vigorous attack on a problem that seems to be within its province. The undertaking is designated as STEP or Science Teaching Emergency Program and is designed to provide some solutions to the critical shortage of science and mathematics teachers at all levels. (*It should be noted that the word "science" as used by the Cooperative Committee includes all the natural sciences and mathematics.*)

In essence the program which has been discussed at length at the last three meetings is as follows:

SCIENCE TEACHING EMERGENCY PROGRAM

I. To encourage departments of science and mathematics in colleges and universities to accept the training of secondary school teachers as a major responsibility.
  A. Recommend that these departments:
    1. Encourage competent students to enter the teaching profession.
    2. Offer programs in science and mathematics for the training of undergraduate teacher candidates that provide the candidates with the necessary subject matter competencies and at the same time permit the satisfaction of certification requirements in education.
    3. Develop graduate level courses in science and mathematics especially designed for teachers already in service and acceptable toward a master's degree in education.
    4. Develop for teachers in service special courses in science and mathematics suitable as refresher courses and provide other sources of information on recent advances.
    5. Assign a staff member as coordinator for this type of program. Where feasible the coordinator may hold a joint appointment in both the subject matter and education departments.
    6. Recognize the importance to college and university staff members of knowledge about and understanding of the problems of secondary schools.
    7. Cooperate with secondary schools through such devices as the loan of a department staff member to a neighboring high school to provide advanced instruction in science for a selected group of students.
    8. Sponsor and support meetings and conferences for teachers.
    9. Encourage employment of women with science training as science and mathematics teachers.
  B. Request that time be set aside in meetings of scientific professional societies for presentation and discussion of the SCIENCE TEACHING EMERGENCY PROGRAM and that this and subsequent reports on the Program be given wide publicity in scientific journals.

II. To assist in the recruitment and training for teaching of individuals with the necessary subject matter competence but without the work in professional education required for certification as teachers.
  A. Encourage the planning of emergency programs and cooperative arrangements in colleges and universities.
    1. For independent liberal arts colleges and engineering schools (Women's colleges represent a particularly important source of teaching talent not yet fully utilized).
      a. Involving cooperation with departments of education in nearby institutions.
        (i) Students transfer for a semester and study professional courses in residence at another institution.
        (ii) Students study professional courses in summer school (e.g. during the summers following the junior and senior years or during the summer following the senior year and the summer following the first year of teaching).
      b. Involving arrangements within the student's original institution.
        (i) Use present staff (e.g. professor of psychology to teach "Educational Psychology," professor of social studies to teach "Foundations of Education," etc.).
        (ii) Employ new, full-time staff to teach courses in education.
        (iii) Employ part-time instructors.
    2. Stimulate ideas and interest in emergency programs.
      a. Conferences with employing schools to study their needs for teachers and their reactions to the proposed programs.
      b. Conferences with state departments of education and certifying agencies concerning the acceptance of candidates completing the programs.
  B. Collect objective and statistical information.
    1. Number of potential students who might qualify and who might be interested in the emergency program outlined above.
    2. Research to measure the effectiveness of these programs.
  C. Seek financial support to provide schol-

arships for capable students enrolled in these programs.

III. To assist in interesting high school students in preparation for teaching careers in science and mathematics.
   A. Create appropriate guidance materials on teaching with special reference to the fields of science and mathematics.
   B. Seek cooperation of scientific and guidance agencies in:
      1. Gathering guidance materials on the teaching of science and mathematics.
      2. Acquaint the membership of these agencies with the special urgency of the crisis in the areas of science and mathematics.
   C. Distribute guidance materials to teachers, counselors, and students.
   D. Publicize opportunities in teaching for women and seek support of women's colleges in this publicity directed to high school students.
   E. Increase support of Junior Academies of Science, the Junior Scientist Assembly and of science fairs, science clubs, science congresses, and science project work.
   F. Promote vocational guidance programs through assemblies, radio and television, and the utilization of scientists and engineers as counselors.
   G. Undertake a basic study of the motivations of individuals in choosing careers in teaching in order to take advantage of a knowledge of these motivations in the preparation of guidance materials.

IV. To support higher salaries for teachers so that beginning salaries, rates of salary advance, and salary ceilings will be comparable with those of engineers and other professional personnel of equivalent training.
   A. Give widespread publicity:
      1. To the prevailing low salaries of secondary school teachers and to the deterioration in the relative economic position of teachers with respect to other occupational groups.
      2. To the special program in the recruitment and retention of science and mathematics teachers because of the competition with industry and government for individuals with training in science and mathematics.
   B. Provide for a study of the various ways in which science teaching can be made more attractive financially through year-round employment, summer employment in science-related industries, or additional pay for directing student research projects, science clubs, science fairs, and the like.
   C. Urge academies of science and other state and local scientific groups to take major responsibility in pressing for higher salaries for teachers.
   D. Offer cooperation to other groups working for an increase in teacher's salaries.
   E. Encourage prominent scientists to lend their influence to these efforts.

V. To promote improved working conditions for and increased efficiency of secondary school teachers of science and mathematics.
   A. Call the attention of the appropriate agencies to the desirability of:
      1. Controlling the size of classes so that more time may be given to the problems of the individual student.
      2. Adjusting teaching load so that a more effective teaching job may be done particularly in connection with laboratory instruction.
      3. Providing adequate instructional facilities and equipment.
      4. Providing consultant help such as is described in Project VII.
      5. Encouraging attendance at professional meetings through provision of time off and reimbursement of travel expenses.
   B. Disseminate available information on satisfactory size of classes, teaching load, and instructional facilities and equipment.
   C. Investigate effectiveness in increasing teaching efficiency of the use of subprofessional teaching assistants and of instructional aids such as motion pictures, radio and television.

VI. To provide for the recognition of exceptionally able teachers through a AAAS program of awards of *Distinguished Service Teacher* citations as a means for improving the status of teaching and the prestige of the secondary school teacher.
   A. Establish regional committees for screening of nominees and a national committee for selection of Distinguished Service Teachers in accordance with established criteria such as the following:
      1. At least five to ten years of recognized successful experience as a classroom teacher of science or mathematics.
      2. Respect of colleagues, students, parents and community.
      3. Education in subject matter field to a level represented by at least one year of graduate work, and recognized scholarship characterized by both depth and breadth.
      4. Adequate professional training and mastery of the standard professional skills and techniques as evidenced by an understanding of youth and by the successful use of a variety of teaching devices.
      5. Original contributions to science or to the art of teaching through research and the increase of knowledge, or through the development of new

devices, books, points of view or practices.
6. Active participation in the affairs of his profession.
7. Interest in and acceptance of responsibility in extra-curricular activities of his school.
8. Maintenance of up-to-date knowledge of developments in scientific fields of interest.
9. Conscientious adherance to high standards of personal and professional ethics.

B. Provide for nominations to be made by any interested individuals or groups but not by direct application.

C. Provide for awards of Distinguished Service Teacher citations to be made by the AAAS.
1. With appropriate ceremony in the teacher's own community.
2. At the next annual meeting of the AAAS to which all Distinguished Service Teachers named during the year are to be invited with travel expenses paid.

VII. To promote the selection and utilization of consultants in mathematics and science on an experimental basis in selected geographic areas.

A. Provide for the selection of five experimental areas, each located in a different state and each meeting the following criteria:
1. Each area should be so bounded as to encompass as many public high schools as will be required to include 40 to 50 full-time science teachers.
2. The area must not include a high school or a school system that employs a science supervisor on either a part-time or a full-time basis. Schools comprising each area should be those wherein each teacher must rely in general upon his own resources for organizing his work. A high perpercentage of young and relatively inexperienced teachers would be desirable.

B. Select and employ a total of ten experienced teachers of proven ability, each capable of functioning as a counselor or consultant in science teaching. Persons employed should possess as nearly as possible all of the qualifications which are listed for the Distinguished Service Teacher of Project VI.

C. Assign two consultants to each of the five areas. One of the consultants should have major training and interest in the biological sciences, the other in the physical sciences and mathematics. It is assumed that arrangements for office space can be made with the chief state school officer or with a sponsoring college or university.

D. Counselors will work on a teacher-to-teacher basis, passing out ideas for the improvement of instruction, suggesting professional literature, discussing subject matter and in general serving as persons to whom teachers can turn for help. In addition counselors will provide such services as:
1. Conferences with groups of teachers on topics ranging from curriculum development and the planning of new facilities to text selection and refresher sessions in specific subject matter areas.
2. A materials center of books, periodicals, tools, raw materials and science equipment. Teachers from the region could use the center to keep posted on new developments or as a place for refresher work. The materials could be distributed on a library loan basis for examination or trial use.

E. Following a trial period of reasonable length, it is expected that there would be an evaluation of the success of the project. Evaluative techniques suitable for use would include the following:
1. The administration of standardized subject matter tests to all students in cooperating schools. Such tests could indicate the success or failure of the program only if similar test scores were available from preceding years, or if the program could extend over a period of two or three years.
2. The collection of data as to the number of students going on into college or university work in scientific fields and comparison with similar figures for previous years.
3. The collection of data as to the degree of participation of high school science students in such activities as Junior Academy meetings, science clubs, and science fairs, and comparison with similar data from preceding years.
4. The analysis of the opinions of cooperating science teachers and of the administrative officers of cooperating schools as to the success of the project.

Your representative strongly supports Projects I through V. Nearly all the ideas and activities expressed therein are consistent with the modern philosophy of education and with the views held by the majority of the members of the NARST.

Your representative however is dubious of Projects VI and VII not because of their lack of intrinsic merit but because of the failure of their proponents to recognize administrative practicalities in the public schools. The difficulty in engineering such

projects would have been apparent had the proponents spent time recently in visiting public schools and discussing them with administrators. However, the basic aims are eminently worthy.

With the reservations just stated, your representative will support these projects unless otherwise directed by the NARST. He urges the membership to do likewise.

Obviously a program as ambitious as this one must be implemented with support and monies beyond those immediately available to the Committee. So far, the following has been done:

1. At the Berkeley meeting of the AAAS Commissioner of Education Brownell and President of the AAAS Weaver appeared on the same symposium, discussed the program and endorsed it. To have two such eminent persons (an educator and a scientist) give such support, amounts to a worthy send-off indeed.

2. At present the Administrative Officers of the AAAS are placing the prestige of the AAAS behind a request to a foundation for a grant to carry out the program, or certain projects in it. While the details cannot be released at the present time, the initial reports are most encouraging.

In summation, your representative is most encouraged by the direction in which the Cooperative Committee now seems to be headed.

AFFILIATION WITH THE AAAS

Procedures for Affiliation

A letter from John A. Behnke, Associate Administrative Secretary of the AAAS explained the procedures for affiliation as follows:

"The procedure for affiliation or association with the AAAS is a relatively simple one. The request must come from the organization wishing to establish a connection with the Association. In addition, the secretary should furnish: (1) a brief history of the organization, including its aims; (2) a copy of the constitution and bylaws currently in force; (3) a recent list of its members and their addresses; (4) the names and addresses of current officers; and (5) a list of any publications sponsored by the organization, with samples, or a list of the major journals in which its members normally publish.

"The request is then forwarded to the Committee on Affiliation and Association and the Committee's recommendation is acted upon by the Board of Directors and later approved by the Council."

Your representative complied immediately with all these stipulations. Hence, on August 3 a letter was received informing the NARST that the Committee on Affiliation and Association unanimously recommended that the NARST be given affiliate status.

At the November meeting of the Board of Directors the request was given approval. Finally on December 27 the AAAS Council gave final and formal approval and the NARST became an affiliate. Your representative was designated to serve on the AAAS Council in addition to his responsibilities on the Cooperative Committee.

Meaning of Affiliation

The following quotation concerning the meaning of affiliation comes from the letter just cited:

"Affiliation or association is a formal indication of the intention of our two organizations to cooperate. It is our hope that the expressed intention will be more than formal and tacit; that it will be real and alive. An Affiliate is entitled to one representative on our Council if less than one hundred of its members are Fellows of the AAAS; two representatives if more than one hundred qualify. We would hope that an appointed or elected delegate would not only represent your wishes accurately but would take a keen personal interest in our problems and program.

"There are no specific responsibilities for an Affiliate, and no financial obligations for either an Affiliate or an Associate. We want to help you and have you help science through us.

"Affiliated and associated societies are privileged—if they wish—to hold national or regional meetings in conjunction with the AAAS national meeting, which is normally held between Christmas and New Years. There is, of course, no obligation for any of our societies to do this.

"However, if your organization should decide to join us in our Christmas meeting, you would be completely free to plan your own sessions. If you preferred, you could join with AAAS Sections in cosponsoring particular programs. In all cases, the Association provides the meeting rooms and projection equipment; prints the completed program; arranges housing through the local housing bureau; and plans for effective publicity—all at no cost to your society. Any of your mem-

bers who presented papers would be eligible for the $1,000 best paper award. Of course, as a former exhibitor myself, I cannot refrain from also mentioning the excellent AAAS Science Exposition.

"On the intangible side—but of great importance—are the exceptional opportunities for sitting in on the significant symposia, research report sessions in related fields, and the conferences. And there are the many personal associations with people from all areas of scientific endeavor."

Your representative wants to express his personal opinion that he believes that affiliation with the AAAS is one of the most significant events in the history of the NARST. The society should be able to make itself known more widely as a result.

SYMPOSIA ON SCIENCE EDUCATION RESEARCH AT THE AAAS CONVENTIONS

At the Berkeley Convention 1954

On Wednesday morning December 29 at 9:00 A.M., Wheeler Hall, University of California there was held a *Symposium: Research in Science Education.*

It was a joint session of the National Association for Research in Science Teaching, National Science Teachers Association, the AAAS Cooperative Committee on the Teaching of Science and Mathematics, and AAAS Section Q—Education; and cosponsored by the Western Society of Naturalists. Because of his proximity to the convention site the major responsibility for organizing the meeting was taken by Dr. Robert Stollberg of San Francisco State College. His zeal and efforts were responsible for an excellent meeting at which the attendance was over 250.

The program was as follows:

ANITA D. LATON, San Jose State College, Presiding

1. Survey of Research in Elementary School Science Education. Jacqueline Buck, Grosse Pointe Public Schools, Grosse Pointe, Mich.
2. Implications of Research in Elementary School Science Education. Matthew Vessel, San Jose State College.
3. Survey of Research in Secondary School Science Education. George G. Mallinson, Western Michigan College of Education, Kalamazoo, Mich.
4. Implications of Research in Secondary School Science Education. Oreon Keeslar, Santa Clara County Schools, California.
5. Survey of Research in College Level General Education Science. Stanley Williamson, Oregon State College, Corvallis, Oregon.
6. Implications of Research in College Level General Education Science. John S. Hensill, San Francisco State College.

The presence of NARST members on the program may be noted.

At the Atlanta Convention 1955

When this report was written only tentative plans had been made for the Atlanta Convention. At the time of publication the program has taken place, and the information given here may be in error. However, any other statement at the time is impossible.

A symposium on *Implications and Applications of Recent Research in Science Education* is being planned tentatively for Wednesday morning, December 28 at Atlanta University subject to the approval of the cooperating societies. Seven societies had agreed to sponsor the symposium, namely, the NARST, National Science Teachers Association, National Association of Biology Teachers, American Educational Research Association, Section Q of the AAAS, the Central Association of Science and Mathematics Teachers, and the Cooperative Committee. Plans are being now made to include as many participants from southern colleges and universities as possible and to plan the same type of program that was offered at Berkeley. Although the NARST will take major responsibility for planning, it must be emphasized that this is *not* an NARST program but one involving *joint cooperation and sponsorship.* It is hoped that it will be as eminently successful as the Berkeley Symposium.

This has been a long report of activity with the AAAS—not because your representative chose to write at length, but rather because the NARST has done so much in its new relationships. As long as your representative continues to work in this capacity, he will endeavor to strengthen the present ties and make them more valuable to both the NARST and AAAS.

FINANCIAL REPORT OF NARST APRIL 19, 1955

RECEIPTS

Balance on Deposit	$592.81
Membership Fees	2,198.00
Total	$2,790.81

EXPENDITURES

Western Michigan College Printing Department—Letterheads and Envelopes.	$35.50
Nathan S. Washton—Railroad fare to Washington, D. C., to attend Future Scientists Meeting	16.68
Kenneth E. Anderson—Stencils and postage	17.15
Printing 1955 NARST Programs	129.21
Secretary Expenses	32.27
Subscriptions to *Science Education* for 1953, 1954, and 1955	2,040.00
Total	$2,270.81
Balance	$520.00

Respectfully submitted,

CLARENCE M. PRUITT,
Treasurer-NARST

OFFICIAL MINUTES OF THE BUSINESS MEETING OF THE NATIONAL ASSOCIATION FOR RESEARCH IN SCIENCE TEACHING, TEACHERS COLLEGE, COLUMBIA UNIVERSITY

APRIL 20, 1955

PRESIDENT Kenneth E. Anderson presided at the Annual business meeting of the National Association for Research in Science Teaching held at Teachers College, Columbia University, April 20, 1955. President Anderson briefly reviewed the activities of NARST during the last year. The official minutes of the last meeting held at the Hotel Sherman in Chicago on March 31, 1954, were approved as published in the April, 1955 issue of *Science Education*.

The report of the Auditing Committee was made by Edith M. Selberg. The Auditing Committee consisted of Charles John Pieper, Edith M. Selberg, and Vaden W. Miles. The Treasurer's book was found to be in balance and the report as accepted is published in this issue of *Science Education*.

The Secretary, Clarence M. Pruitt, reported the passing of NARST members during the past year as follows: Alden H. Struble, Washington, D. C. Public Schools; L. Paul Elliott, University of Florida, Gainesville; and W. C. Croxton, St. Cloud Teachers College, St. Cloud, Minnesota.

It was moved and seconded that the Secretary be empowered to convey to Mrs. Struble, Mrs. Elliott, and Mrs. Croxton respectfully the heartfelt sympathy of the NARST at the untimely passing of these valued members of NARST.

It was moved by Vaden W. Miles, seconded and passed that official letters of appreciation be sent to Professors Hubert M. Evans and Fred L. Fitzpatrick of Teachers College for assistance and courtesies in many ways in making local arrangements for the present meeting.

It was moved, seconded, and passed that letters of greeting from the Association be sent to Drs. S. Ralph Powers, Ellsworth S. Obourn, H. Emmett Brown, Stanley Brown, and Willard Jacobson. These persons are presently serving in foreign countries.

Dr. George G. Mallinson, NARST representative on the Cooperative Committee on the Teaching of Science and Mathematics of the AAAS made his annual report on the activities of this Committee. (See complete report in this issue of *Science Education*). It was moved, seconded, and carried that the report be accepted as presented. Dr. Mallinson reported an excellent NARST program at the Berkeley meeting of the AAAS in December. Plans were described for the December, 1955, Atlanta meeting of AAAS in cooperation with the National Biology Teachers Association, National Science Teachers Association, Central Association of Science and Mathematics Teachers, and Section Q in Education of the AAAS. Dr. Mallinson led a discussion on the affiliation of the National Association for Research in Science Teaching with the American Association for the Advancement of Science.

Dr. Nathan S. Washton made a report on his attendance at a meeting in Washington of the Future Scientists of America Foundation. (Report published in this issue of *Science Education.*) The report was accepted as presented.

A rather lengthy discussion was held regarding the retention of some members of NARST who are delinquent in dues. A number of NARST members personally well known to these delinquent members agreed to write to them to persuade them to retain their NARST membership.

Dr. Herbert A. Smith, Chairman of the Third Annual Review of Research in Science Teaching, made a progress report. His report was supplemented by reports from each of the level chairmen: Jacqueline Buck Mallinson, Clarence H. Nelson, and Thomas P. Fraser. Good progress seems to be being made for getting the report in excellent shape for publication in the December, 1955, *Science Education.* Comments were made by Blackwood, Anderson, Phil Johnson, Gruenberg, Washton, Pruitt, and Van Deventer.

Herbert A. Smith, Chairman, made the report for the Nominating Committee. Other members of the Nominating Committee were Thomas P. Fraser and Clarence H. Nelson. The Nominating Committee presented the following slate of names for officers for 1955–56:

President: William C. Van Deventer
Vice-President: Waldo W. E. Blanchet
Secretary-Treasurer: Clarence M. Pruitt
Executive Committee: Kenneth E. Anderson, Nathan S. Washton.

Nominations from the floor were called for. It was moved and seconded that the report of the Nominating Committee be accepted and that the Secretary be empowered to cast a unanimous ballot for those named by the Nominating Committee. The motion carried.

It was decided to hold the next annual meeting in Chicago at a date to be decided later.

A motion was made that the 1955 business meeting be adjourned. The motion carried.

EXECUTIVE COMMITTEE MEETING

April 20, 1955

Some discussion was held relative to the 1956 Chicago meeting and the desirability

of meeting at the time of the ACTE meeting—either prior to or following this meeting.

Committee Level Chairmen for the Fourth Annual Research Report were considered at some length.

Professor Thomas P. Fraser of Morgan State College, Baltimore, Maryland, was appointed Chairman of a Committee on Needed Research in Science Teaching. Other members of this committee are Dean Waldo W. E. Blanchet of the Fort Valley State College, Fort Valley, Georgia and the various Level Chairmen.

Dr. George G. Mallinson was appointed NARST representative to the AAAS.

Drs. Herbert A. Smith and Clarence M. Pruitt were appointed on a Committee for Cooperation with the U. S. Office of Education.

The meeting was adjourned.

DINNER MEETING

Some fifty persons attended the annual dinner meeting at noon April 20th. NARST members present: Cyrus W. Barnes, Vaden W. Miles, Paul E. Blackwood, William C. Van Deventer, George G. Mallinson, Jacqueline Buck Mallinson, Thomas P. Fraser, Gordon M. Dunning, Kenneth E. Anderson, Waldo W. E. Blanchet, Herbert A. Smith, George Davis, Clarence H. Nelson, Edward K. Weaver, Nathan S. Washton, Finley Carpenter, Velma M. Huntley, Hubert M. Evans, Nathan Neal, Robert MacCurdy, Vernon C. Lingren, Chester A. Lawson, Edith M. Selberg, Elwood D. Heiss, Clarence H. Boeck, Martin L. Robertson, Benj. C. Gruenberg, Clarence M. Pruitt, and Rose Lammel.

BOOK REVIEWS

FARRELL, B. A. (Editor). *Experimental Psychology*. New York (15 East 40th Street): Philosophical Library, 1955. 66 P. $2.75.

Experimental Psychology is a series of six broadcasts over the British Broadcasting system on recent research in psychology. The general purpose of the broadcasts was to clear up certain misconceptions prevalent about experimental psychology. The broadcasts describe the sort of work being pursued at the present time and also to indicate the general attitude which experimental psychologists develop in their attempt to obtain a scientific understanding of the activities of human beings and sub-human organisms.

Dr. A. J. Watson discusses perception; Dr. Harry Kay describes research in Adult Learning and Remembering; Dr. J. A. Deutsch tells about Motivation; Dr. B. A. Farrell explains Some Hypotheses of Psycho-Analysis; Dr. Michael Argyle discusses The Study of Social Behavior; and Dr. R. C. Oldsfield considers The Prospects of Experimental Psychology.

MACDONALD, MARGERET (Editor). *Philosophy and Analysis*. New York (15 East 40th Street): Philosophical Library, 1954. 296 P. $7.50.

This is a collection of articles on analytic and linguistic philosophy published in *Analysis* (British publication) between 1933–40 and 1947–53. Numerous writers are represented and many topics discussed such as: the relations between knowing, believing, and asserting; logic and psychoanalysis; the analysis of temporal propositions; probability and natural law; and the problem of truth.

SMITH, MAURICE (Editor). *Flight Handbook*. New York (15 East 40th Street): Philosophical Library, 1955. 282 P. $6.00.

Flight Handbook presents the theory and practice of aeronautics. This is the fifth edition—first published in 1910. It was compiled by the Staff of *Flight*, a British publication. There are 217 photographs and drawings and 12 illustrations inset.

The textual material deals with the atmosphere and its effects on flying, first principles of aerodynamics, aircraft structure, controls, landing gears, gliders, sailplanes, rotorcraft, balloons, airships, piston engines, gas turbines, ramjets, pulsejets, rockets, navigation, instruments, and navigation.

KIRKALDY, J. F. *General Principles of Geology*. New York (15 East 40th Street): Philosophical Library, 1955. 327 P. $6.00.

This book is a general introduction to the study of geology. Various phases are considered: Basic principles, Physical Geology and geomor-

phology, Petrology and mineralogy, Composition and origin of the Earth, Historical Geology, and Economic Geology. The author, Dr. Kirkaldy is a Reader in Geology in the University of London. The book is interestingly written, aptly illustrated. Naturally a great deal of the illustrative material refers to the British Isles and Europe. This makes it an excellent reference for American readers.

ABBEY, STATON. *Horner's Dictionary of Mechanical Engineering Terms.* New York (15 East 40th Street): Philosophical Library, 1955. 417 P. $6.50.

This is the seventh edition of a dictionary first written by Mr. J. G. Horner and now revised by Mr. Abbey. The dictionary is in a way a condensed encyclopedia of mechanical engineering practice.

HUME-ROTHERY, WILLIAM. *Electrons, Atoms, Metals, and Alloys.* New York (15 East 40th Street): Philosophical Library, Inc., 1955. 387 P. $10.00.

Non-mathematical readers find it difficult to understand the application of the electron theory to the structure and properties of metals and alloys. In at least one respect this is a unique book—at least in such a technical field. The subject matter is presented throughout in the form of a dialogue between an Old Metallurgist and a Young Scientist, bringing out clearly the contrast between the old and new viewpoints.

RICHARDSON, K. I. T. *The Gyroscope Applied.* New York (15 East 40th Street): Philosophical Library, Inc., 1954. 384 P. $15.00.

Not so many years ago the gyroscope was comparatively unknown, except possibly as a toy, involving a wheel spinning in some form of framework which could be made to balance on the edge of a penknife, the rim of a glass, or on a piece of string. The name gyroscope dates back to 1852 when Foucault used it to demonstrate the rotation of the earth.

Today, the gyroscope plays an important part in the navigation and control of ships and aircraft, in gunfire control, bomb sights, in the torpedo, and more recently in the guided missile.

This book is believed to be the most comprehensive book available on different types of applications of gyroscopes. The author has been closely associated with developments in this area.

GRAY, ERNEST A. *Microbiology: An Introduction.* New York (15 East 40th Street): Philosophical Library, 1955. 175 P. $3.75.

This book is designed as a simple introduction to microbiology. It is based on the author's many years of experience in teaching the subject at the University of Cambridge. The historical background of the area is stressed as microbiology goes back more than three centuries. Ecology of micro-organisms is also stressed.

WILLIAMS, TREVOR ILLTYD. *The Elements of Chromatography.* New York (15 East 40th Street): Philosophical Library. 90 P. $3.50.

Chromatography has had a rapid development in the last decade and is now finding a place in the curricula of many leading universities. This book gives a general survey of the method as practiced today.

WILSON, WILLIAM. *The Microphysical World.* New York (15 East 40th Street): Philosophical Library, 1954. 216 P. $3.75.

This book is concerned with the small things of the physical world especially the atoms, their structure and bahavior. The treatment is somewhat historical, starting out with Dalton's atom and coming down to the present. The treatment is non-mathematical and the book is designed primarily for the layman. High school chemistry teachers will find the book most useful and refreshing.

MAINX, FELIX. *Foundations of Biology.* Chicago (5750 Ellis Avenue): The University of Chicago Press, 1955. 86 P. $2.00.

This pamphlet considers the ways of work in biology: (1) The Elementary Points of View (The Morphological, the Physiological, and the Genetical); (2) The Complex Points of View (The Organism as an Open System; The History of Organism, Organic Diversity and Its Structure; The Population as the Natural Form of Existence in Living Things), (3) The Psychological Function of Speculation in Biology, (4), Parabiology, and (5) World Picture and Philosophy of Life.

WOLFSON, ALBERT AND RYON, ARNOLD. *The Earthworm.* Evanston, Illinois: Row, Peterson and Company, 1955.

This is a unitext showing biology in a new dimension. It is a book on dissection of the earthworm especially suitable for high school and college biology classes. The book is unique in having a series of color plates in transparent plastic which enables the various systems to be transposed one over the other as the occasion demands. This should greatly facilitate learning. There are also 14 figures in color. Books such as these should be of great value in dissection work and facilitating understanding in biology.

ZUFFANTI, SAVERIO; VERNON, ARTHUR S.; AND LUDER, W. F. *A Laboratory Manual of General Chemistry.* Philadelphia: W. B. Saunders Company, 1955. 310 P.

The manual, primarily written for the authors' *General Chemistry* text, may be used with any

college chemistry text. More than the usual space is devoted to qualitative analysis. However the first 40 experiments are sufficient for a year's work in chemistry without any qualitative experiments.

TURNER, C. DONNELL. *General Endocrinology.* Philadelphia: W. B. Saunders Company, 1955. 553 P.

This is the second editon of a text first published in 1948, completely revised and brought up to date. This book would serve excellently as either a basic text in a course or as a general reference in the field. The book is well-written and well-illustrated.

MARSHALL, CLYDE AND LAZIER, EDGER L. *An Introduction to Human Anatomy.* Philadelphia: W. B. Saunders Company, 1955. 420 P. $4.50.

This is the fourth edition of a textbook first published in 1935. The book is written from the standpoint of an anatomist. There are brief accounts of the functional activities of different organs and related problems of practical interest.

ROMER, ALFRED SHERWOOD. *The Vertebrate Body.* Philadelphia: W. B. Saunders Company, 1955. 664 P.

This is the second edition of a college text first published in 1949. Numerous changes have been made, more of a minor nature. The point of view is developmental and is a truly comparative treatment. Consideration is given to function. All parts of the vertebrate anatomy are considered. There are nearly 400 illustrations which are important to an understanding of the textual material. This book seems to be an unusually fine text and would also serve as an authoritative reference.

RUSK, ROGER D. *Introduction to College Physics.* New York (35 West 32nd Street): Appleton-Century-Crofts, Inc., 1954. 816 P. $6.50.

This book on college physics should serve adequately both those students who will take only one year of college physics as well as those students who will take more courses in college physics. The fundamentals of classical physics are retained but developments in modern physics are not neglected. The reviewer especially likes the presentation of subject matter in this text, the well-selected problems at the end of various chapters, and the readable literary style. Certainly this is one of the better recent college texts in physics. Dr. Rusk is professor of physics at Mount Holyoke College.

MARKHAM, EDWIN C. AND REILLEY, CHARLES N. *A Laboratory Manual for General Chemistry.* Boston: Houghton Mifflin Company, 1954. 424 P. $3.00.

The authors state that "a laboratory manual for general chemistry should supplement the textbook used in the course by illustrating certain facts and principles and by introducing certain new but related material. It should have as its aim the development of the student's technical skill, the whetting of his interest in the experimental approach to chemistry, and, by providing a certain kind of entertainment, should arouse his curiosity."

The eighty experiments should permit of a wide choice by users of the manual. The general order follows the outline of the Markham and Smith *General Chemistry.*

JONES, JR., W. NORTON. *General Chemistry.* New York: The Blakiston Company, 1954. 907 P. $6.50.

General Chemistry is a first-year college chemistry text intended for use by students having and those not having high school chemistry. Atomic structure and periodic classification receive early treatment. Special emphasis is placed on the structure of molecules and solids. The comprehensive coverage of this text permits or even necessitates selection of the content discussed.

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